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Farming in Tsetse Controlled Areas

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FARMING IN TSETSE CONTROLLED AREAS
FITCA

Environmental Monitoring and Management Component

EMMC

Project Number : 7.ACP.RP.R. 578

Land-use/ land-cover change analysis for Ghibe Valley - Ethiopia: 1993-2003

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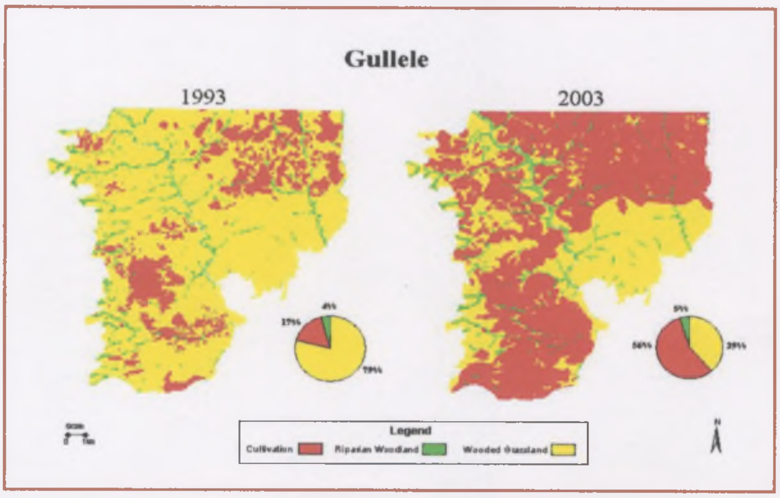

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Summary

- This study (conducted March-May, 2003) shows the 10 years of change in land use after tsetse control in the upper Ghibe Valley of Ethiopia between 1993 and 2003.

- An Enhanced Landsat Thematic-Mapper (TM-7) satellite image for February 2003 was acquired, ground-truthed, hand-interpreted and analyzed to compare to previous land-use/ land-cover maps created from Landsat TM imagery for this area from 1993.

- Expansion of cultivation after tsetse control was exceptionally high, with a 231% increase in the area of land cultivated between 1993 and 2003 in the area where tsetse control has been most consistent and successful. The increase in cultivated area at the other study sites, where tsetse control was intermittent, ranged from 101%-182%. It is plausible that tsetse control has played a significant causal role in this rapid expansion in land use in Ghibe Valley. However, more detailed studies are needed to confirm the relative importance of tsetse control compared to other factors (land policy, intrinsic human population growth, others) in causing the measured changes.

- The high speed and significant magnitude of expansion of cropland is highly unusual in Africa in the experience of the land-use team at ILRI. Changes in land use in other areas with tsetse control have been slower and less extensive.

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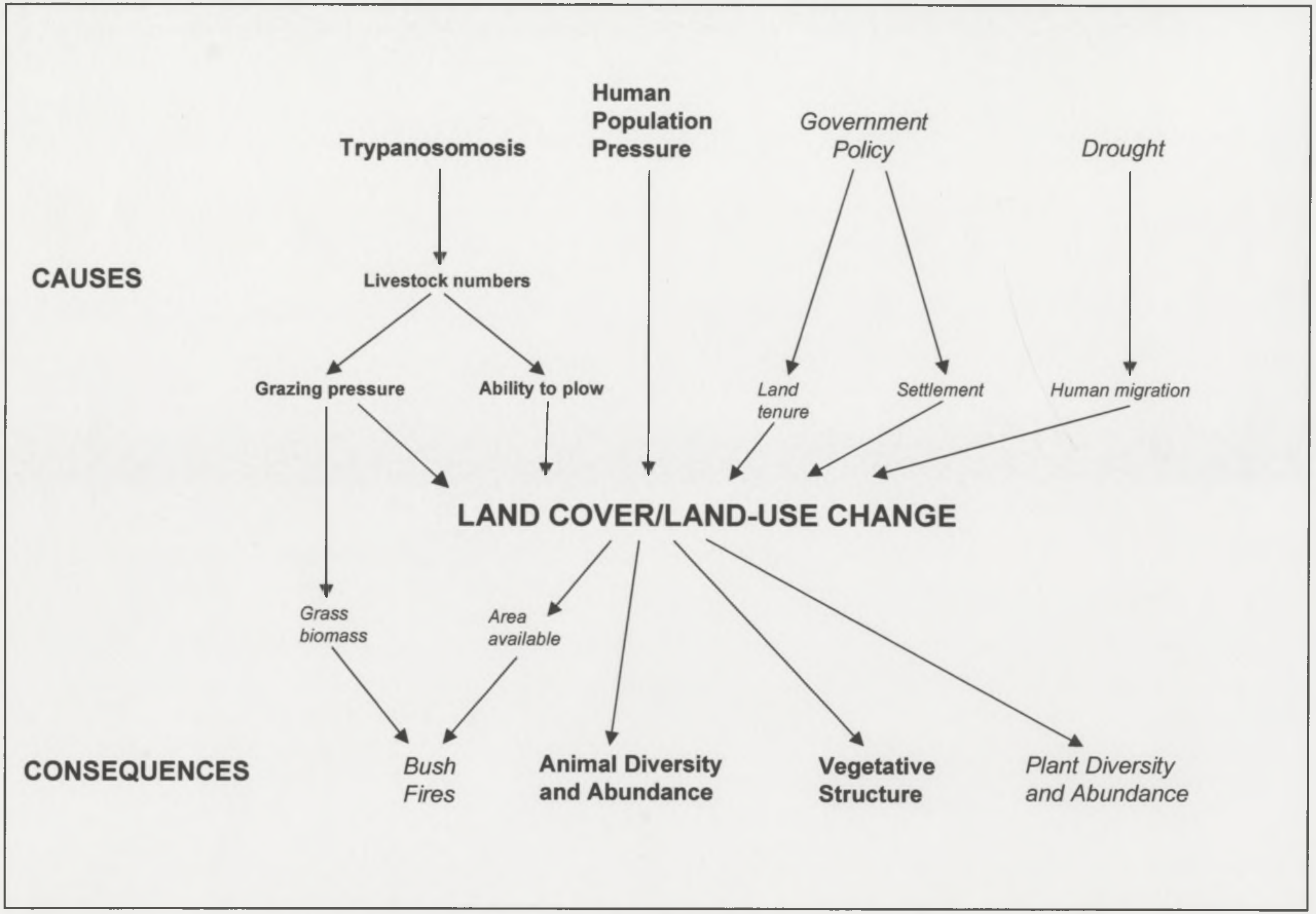
Introduction

In the later part of the twentieth century there has be a impressive increase in the conversion of grassland, woodland and forest into cropland and pasture in the tropics (Houghton 1994, Williams 1994, Reid et al 1997). In Africa there are many possible reasons for this increase in cropland, which include human population growth and the subsequent increase in demand for food; socio-political changes; policy; drought; land tenure reform; and control of human and livestock diseases (Reid et al. 2000, Bourn 2001). It is thought that control of trypanosomosis, transmitted by the tsetse fly, will allow pastoralists to expand grazing areas and farmers to expand cultivation into large tracts of Africa previously little used by people (Jordan 1986). These same areas, because of low levels of human use, have high ecological and natural resource value. Thus, the prospect of control of trypanosomosis lies at the centre of a perceived conflict between food needs of rural peoples and environmental conservation. This report documents recent and dramatic changes in land use in southwestern Ethiopia in response to settlement policy, drought, land tenure change and control of the livestock disease, trypanosomosis.

Reid et al (1999) stated that recent remote sensing and oral history/ recall studies across Africa '*...demonstrate that control of trypanosomosis can cause agricultural expansion. In some places, trypanosomosis appears to be only one of several factors affecting expansion, and in others its effect dominates.*' These factors and other possible causes and ecological consequences of land cover/land use change are illustrated in Figure 1.

In the upper Ghibe Valley in southwestern Ethiopia, the land has been cultivated for decades and possibly thousands of years. The International Livestock Research Institute (ILRI) has been working in the Ghibe Valley since 1986 to control the tsetse fly and improve human welfare. In 1993, the ILRI environmental impacts team conducted a land-use/land cover change analysis and biodiversity surveys in this region (Reid et al., 1997, 1999, 2000, 2001, Reid 1999,Wilson et al. 1997). This land-use/ land-cover change analysis covered the years 1957, 1973, 1987, and 1993. The cultivation over that time period went through a series of expansions and contractions as a result of the ebb and flow of land-use practices caused by changes in policy, human populations, drought and the severity of trypanosomosis. In 1991, ILRI successfully controlled the tsetse fly one area (Gullele) of Ghibe valley. The purpose of this study was to update these previous studies and assess the changes in land use and land cover in the 12 years following mostly successful control of the tsetse fly (1991-2003) in part of the valley, using LANDSAT satellite imagery/GIS and compare these results with those conducted by ILRI environmental impacts team in 1993. This research was funded by the EMMC (Environmental Monitoring and Management) component of the FITCA project (Farming in Tsetse Controlled Areas), which is a sub-contract from AU-IBAR (African Union – International Bureau of Animal Resources) to ILRI (International Livestock Research Institute) funded by the EU (European Union) (see Appendix I for Terms of reference).

Figure 1. Possible causes and consequences of land cover and land use change (from Reid et al. 2000).



Methods

Portions of this section were extracted from Wilson et al 1997and Reid et al. 2000.

Ghibe Valley is located in southwestern of Ethiopia (Figure 2). The study area, which is approximately 40 km X 40 km, is situated between 37°15' and 37°40' east longitude and 8°05' and 8°15' north latitude. This part of Ghibe Valley receives, on average, about 1300 mm of rainfall a year and is located in the part of Ethiopia that receives the most reliable precipitation each year (EMA 1988). There has been no drought in Ghibe in the last 10 years (Woudyalew Mulatu, personal communication

The Ghibe River runs through the center of the study area and forms the headwaters of the Omo River that flows into the Rift Valley and Lake Turkana in northern Kenya. The river, starting from the north, progressively cuts more deeply into a plateau (1600 m elevation) that covers most of the study area. The Boter Becho mountains form the western border of the area; these mountains reach about 2300 m and are densely forested. To the east, the land rises to 2000 m and forms the beginning of the vast Ethiopian highlands, which are the most extensive highlands in Africa. The Ghibe River itself flows from north to south, flowing into the study area at 1400 m elevation in the north and leaving the study area at 1000 m through a deep gorge in the south.

The vegetation varies from dense forest in the west to thinly vegetated wooded grasslands that cover most of the plateau area (Reid et al., 1997). The steep slopes forming the river gorge are covered by deciduous woodland dominated by several tree species in the genera, *Combretum* and *Terminalia.* A thin ribbon of riparian woodland grows along the primary and secondary streams and rivers that reticulate across the landscape. These riparian woodlands are dominated by trees (*Aningera sp., Syzygium sp.*) that are not found elsewhere in the valley. The most sparsely wooded areas, the wooded grasslands (about 10% woody canopy cover, 90% open grassland), are dominated by several species of *Acacia* and *Combretum.* These latter grasslands are burned heavily each year by people and the burning probably retards woody vegetative regrowth. (see Photo 1 for general landscape photograph).

Photo 1. General photograph of the Ghibe Valley from the Welkite road overlook.

Despite the high rainfall, the vegetative physiognomy is dominated by wooded grasslands (61% cover in 1993, Reid et al., 1997), with drainages lined by riparian woodlands (3% cover in 1993). The grasslands are infested principally by only one species of tsetse fly, *Glossina morsitans submorsitans* Newstead., while the woodlands are infested by three species of fly, *G. morsitans*, *G. pallidipes* Austen, and *G. fuscipes fuscipes* Newstead (Leak et al. 1993). The grasslands are dominated principally by grasses (*Hyparrhenia dregeana, Hyparrhenia filipendula, and Bothriochloa insculpta*) with less abundant leafy herbaceous plants (*Leucas deflexa and Vernonia congolensis*) and scattered acacia and fig trees (*Acacia polycantha, A. seyal, A. sieberiana and Ficus sycomorus*). Reid et al., (1997) hypothesize that these grasslands are of secondary nature, derived from a more densely wooded landscape, with some limited areas of natural open grassland. Even though the riparian woodlands are relatively rare, they are crucial ecologically because they support most of the biological diversity in the area. These woodlands are dominated by *Syzigium guineense, A. polyacantha* and *F. sycomorus*. Upland woodlands dominate small patches of the landscape (9% cover in 1993) and support several species of *Acacia, Terminalia*, and *Combretum*. Some of the wooded grasslands grow on seasonally flooded vertisols and thus are edaphic in origin; the rest of the grasslands (and woodlands) grow on a variety of lighter red clays. Although one would expect to see a sharp distinction in the vegetation supported by these two soil types, we hypothesize that this distinction is blurred by gradual soil transitions, human use and fire.

Four study sites within the study area were selected to be able to assess the effects of tsetse control over time. The design assesses the impacts of tsetse control in two different ways: 1) the effects of changes in land use over time in areas with different levels of tsetse control and 2) a contemporary comparison over space, but at the same time, of areas with different levels of successful tsetse control. These two methods were used to make the most robust comparisons possible of the impacts of tsetse control on land-use change, and to attempt to distinguish the effects of tsetse control from other factors that cause changes in land use. The study area was thus defined to include a site (Gullele) where there has been nine years of consistent and successful control of the tsetse fly between 1991 and 2000 and three adjacent sites (Gerangera, Ghibe and Kumbi) that were biophysically similar to Gullele where some low-level, intermittent tsetse control has taken place over time. We attempted to find areas of the valley with similar climate, soils and vegetation where there had been no tsetse control at all, but no such area exists. The area is infested with the three species of tsetse fly mentioned above. The infestation of the fly is limited by elevation, with heavy fly infestation below 1500-1800 m, little between 1800-2000 m and none above 2000 m. All study sites were limited to areas below 1800 m. Successful tsetse control began in about a 200 km^2 portion of the study area in January, 1991, at the Gullele site using an insecticidal 'pour-on' preparation (cypermethrin) applied along the backline of cattle (Leak et al., 1995). The other sites have had sporatic tsetse control efforts using targets, pour-on, and treatment for cattle (see section below).

Most farmers in Ghibe Valley, Ethiopia, have small plots (0.2 to 6 hectares) that they either plough by hand with a hoe or with an oxen team and plough (Swallow unpublished data). In the early 1990's, however, large-scale farming came to Ghibe; these farms can be up to 400 ha and are ploughed with tractors. Most farmers cultivate principally maize, sorghum, and tef, regardless of farm size. Tef is an indigenous species of grass (*Eragrostis tef*); bread made from tef flour is a preferred staple food in Ethiopia. Farmers also cultivate fava beans, niger seed, false banana (enset), chickpeas, sesame seed, hot peppers, and wheat.

In 1993, smallholder farms covered about a quarter of three of the four study sites (Gullele, Kumbi, Gerangera), while largeholder farms covered less than 1% of the land area (Reid et al., 1997). We calculate that about 90% of these three study sites support soils that are moderately to highly suitable for agriculture (see descriptions of these land-use types below).

Figure 2. Map showing the location of Ghibe Valley, Ethiopia and the specific area of study (from Wilson et al. 1997).

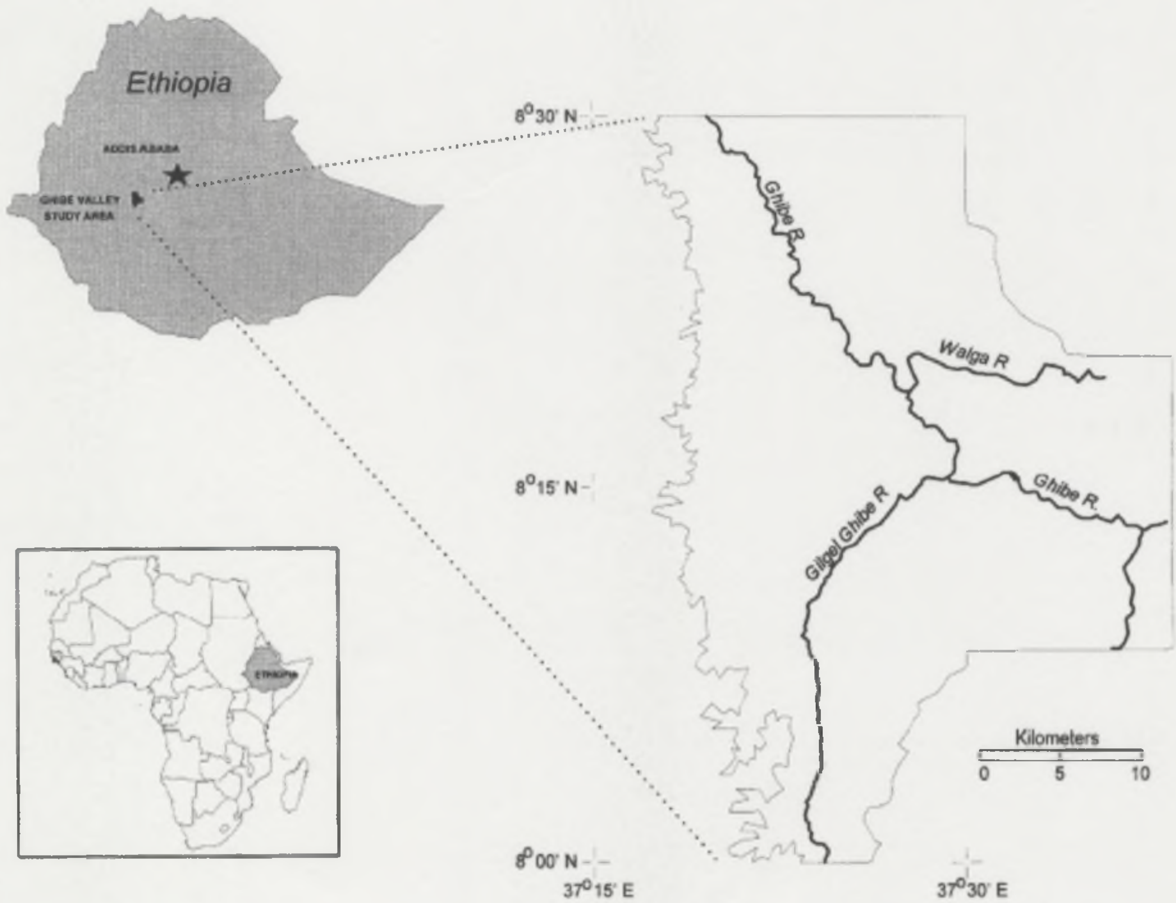


Figure 3. The characteristics of the four study sites of Ghibe Valley, Ethiopia considered in this study.
(From Wilson et al. 1997).

	GULLELE	GHIBE	GERANGERA	KUMBI
Tsetse CONTROL EFFORTS	Insecticidal pour-on Started in 1991 Successful control by 1996, with some resurgence in 2000	Insecticidal targets; pour-on 1991, 1995 Not successful	Pour-on and treatment at crush near the area. 1994/5 Success unknown	1994/5 Sporatic Trypanocidals; Spot-on Success unknown
AREA (km^{2})	293	109	119	59
ELEVATION (m)	1385-1800	1064-1464	1338-1817	1453-1815
SOILS	Heavy black clays (vertisols) in lowlands, red clay on hills	Heavy black clays (vertisols) in lowlands, many very rocky areas	Heavy black clays (vertisols) in lowlands, red clay on hills	Heavy black clays (vertisols) in lowlands, many very rocky areas
ROAD ACCESS	Good dirt road through center of area	Very good tarmac road (road to Jima)	Very poor track through some of the area	Very good tarmac road (road to Jima) at edge of area

Site Descriptions and Tsetse Control Efforts in Each of the Four Study Sites

Below are summaries of the characteristics of each of the four Ghibe Valley study sites (also see Figure 3, above.

Gullele

Tsetse control began in 1991 and was successful by 1996. The control was advertised by ILRI and many farming families migrated to the area when they heard about the successful tsetse control there. The land is very fertile land in Gullele and migrants are agriculturalists and thus came to plough the land for crop cultivation (Woudyalew Mulatu, personal communication). Smallholder farming is composed primarily of tef, maize and sorghum crops. Road access to this area is good with a dirt road running through the centre of the study site.

The following was extracted from a technical report written by John Rowlands to ILRI in April 2002:

1991 In an attempt to control trypanosomosis, a tsetse control trial was started in upper Ghibe (Gullele) using a synthetic pyrethroid cypermethrin 'pour-on' (known as ECTOPOR) applied monthly to cattle. For the first two years the treatment was given free of charge to owners of approximately 1750 cattle covering an area of about 125 km^2.

1996 An analysis of the results of the 'pour-on' trial showed that the number of tsetse had been reduced by 95% over the five years and the trypanosome prevalence in cattle by 63%. Application of the pour-on had also significantly reduced the numbers of biting flies. In terms of livestock productivity there were significant improvements in both birth rate and calf mortality. The numbers of calves alive at weaning doubled. This has led to huge numbers of cattle to be seen today partly through herd growth and partly through immigration of other people into the area. For example, one farmer with cattle in the herd being monitored has 40 cattle now compared with 4 in 1990.

2000 With a reduction in research funding, tsetse control operations at Ghibe became unsustainable and ILRI was no longer able to purchase and supply the pour-on. *As a result the tsetse population has increased and cattle today are again becoming clinically sick.*

Gerangera

This site is south of Gullele and separated from Gullele by a government military camp that is approximately 6 kilometers wide. Thus, the control in the southern Gullele town of Tolley was assessable to some of the farmers at Gerangera, if they chose to walk their cattle through the military camp to the treatment crush in the town of Tolley.. This could have helped the control of tsetse/tryps (Woudyalew Mulatu personal communication). Interviews by the ILRI environmental impacts teams in 1994 with Gerangera farmers revealed that some farmers did herd their cattle to the crush for treatment but not all farmers did this and those who did often missed some of the treatments (Reid unpublished data). There is expansion of cultivation using tractors currently at the northern edge of this study site (near Tolley Military camp). The military camp proposes to cultivate 800 hectares, and currently this is in process. Smallholder farming is composed primarily of tef, maize and sorghum crops. Soils, climate and potential vegetation in this area are similar to Gullele study site. Road access to this area if very poor, however, and thus this site is much less accessible than any of the other three sites.

Kumbi

'Spontaneous' tsetse/tryps control efforts have been occurring since 1994/5, when requested by farmers. This could be helping control tsetse/tryps (Woudyalew Mulatu, personal communication).

People are of an agro-pastoral culture. They tend to grow more enset, sorghum than in the other three sites and less tef. Farmers tend to leave trees for shade and bee keeping, with many more trees around villages and in farmer's field than in the other three sites.

Soils are vertisols in the lower areas and red clay soils on the ridgetops, similar to the other three sites. Road access is excellent at the southern and higher elevation (and less tsetse-infested) end of Kumbi by the main tarmac road from Addis to Jimma, but poor at the northern, lower elevation (and more tsetse infested) part of the study site.

Ghibe

Trial efforts were attempted in 1991 and 1995by ILCA/ILRI using insecticide targets and then pour-on. These efforts had some impact on the fly populations but was not considered successful control (Woudyalew Mulatu, personal communication).

A large state farm has been established in this area since the 1960's along the Ghibe River. The state farm has brought many of the migrants into this area. The migrants settle here and grow niger seed, tef, maize and sesame. The state farm is located on alluvial vertisols with heavy rocky and lighter red clay soils on the hills. Road access is excellent by the tarmac road from Addis to Jima which bisects the valley.

Trees are protected by local community on the north side of the Ghibe River. This land was used by largeholder investors in the early 1990's but has since been abandoned and is now converting to woodland grassland.

Figure 4. Description of land-use/land-cover types analysed in this study. (Adapted from Reid et al. 1997).

Riparian Woodland	Wooded Grassland	Cultivation (Oxen-ploughed)	State Farm (Tractor-ploughed))
Dominant Trees			
Syzygium guineense *Stereospermum kunthiunum*	*Acacia polyacantha* *Ficus sycomorus*	*Acacia polyacantha* *Cordia africana*	*Acacia polyacantha* *Ficus sycomorus*
Woody Canopy Cover			
33% Trees	6% Trees	4% Trees	0.6% Trees
20% Shrubs	3% Shrubs	2% Shrubs	0.1% Shrubs
53% Total	9% Total	6% Total	0.7% Total
Herbaceous Layer			
1.2m Height	1.8m Height	1.6m Height	0.4m Height
78% Cover	96% Cover	82% Cover	31% Cover
Cultivation			
0% Cover	0% Cover	57% Cover	96% Cover
337m from nearest field	701m from nearest field	Sorghum/maize/tef	Chickpeas/simsim /citrus

Major Land use Type Descriptions

Smallholder Cultivation

Smallholder cultivation is described in Wilson et al., 1997 and Reid et al., 2000 (also Figure 4). Smallholder farmers grow a diversity of crop types, including maize, sorghum, tef, noug or niger seed, false banana, groundnuts, wheat, beans and hot peppers. These farmers plough the land mostly by hand hoe or with a pair of oxen and are the direct beneficiaries of a tsetse control program in Gullele run by farmers with the assistance of ILRI . Often smallholder farmers leave trees for shade and hedgerows resulting in a 6% canopy cover (especially in the Kumbi study site as noted above), however, in some portions of Ghibe this is changing. Fields range in size from 0.25-4.0 hectares. *See Photo 2.*

Photo 2. An example of smallholder cultivation land use type (Kumbi area).

State Farm (Largeholder) Cultivation

This large government-run farm grows a number of crops for market (citrus, onions, maize, spices) and ploughs exclusively by tractor. Virtually all trees and shrubs are removed for this type of cultivation resulting in 96% cover of crops (Reid et al., 2000) *See Photo 3.*

Photo 3. An example of tractor-ploughed, state farm cultivation (Ghibe area).

Wooded Grassland

The wooded grassland land cover type is predominately open woodland with a canopy cover of 9%. These large uncultivated portions of the grasslands and woodlands are used for settlements, hunting, wild plant gathering, bee keeping, livestock grazing, fuel wood collection, charcoal making, and woodlot cultivation. This land cover type includes upland woodlands, which typically have higher canopy cover and include shrub lands (Reid et al., 2000). *See Photo 4.*

Photo 4. An example of wooded grassland land cover type (Gerangera area).

Riparian Woodland

Riparian woodlands occur along river courses and normally have dense canopy cover (totaling nearly 53%; Figure 5). The dense vegetation and availability of water make these areas of high biodiversity (Wilson et al., 1997). *See Photo 5*

Photo 5. An example of riparian woodlands land cover type (Ghibe area).

Image Acquisition and Preparation

A Landsat Thematic Mapper Enhanced 7 (TM-7) Image (Path 169, Row 55) for 20 February 2003, was acquired from the United States Geological Survey (USGS). This satellite platform has the same 7 bands with 30-m resolution as older TM-7 images; however, it has an added panchromatic 8^{th} band with a resolution of 15 meters. This 15-m band enhances (i.e., sharpens) the other 7 bands of the image giving an improved picture of the landscape. ERDAS Remote Sensing software (Version 8.4 cite ERDAS here) was used for the registration, the creation of image composites and classifications. The image was downloaded via the Internet in TIFF format and cropped to about a quarter of the original scene size (to include only the Ghibe study site). This cropping reduced the file size and made the imagery files more manageable. For rectification (geo-referencing) of the imagery, previously digitized rivers and roads were used as training sites. Also, features on scanned topographic maps were used for additional accuracy. Once each image band file was rectified it was compared to the previous, 1993, image to make sure they corresponded. The next step was to make composite files of several bands for image analysis. In the previous study (Reid et al. 2000), a composite of bands 3-4-7 was used for hand interpretation. To make the analysis comparable the same composite was made for 2003 image. For this type of analysis, band combinations of 3-4-5 also produce good results. In addition to these bands, band 8 was added to the 2003 image composition, this made the resulting imagery sharper.

An unsupervised classification dividing the area into 15 categories was conducted using ERDAS for reference in the field. In the ARCVIEW GIS program (ESRI, Version 3.3a), each study site (Gullele, Ghibe, Kumbi and Gerangera) was isolated using previously digitized maps. A one–kilometer A UTM (Universal Trans Mercator) grid was overlaid on the image as well as the roads to assist in locating specific areas on the image for collection ground control points (GCP) to ground-truth the image. Hardcopies of both the unclassified (raw image) and the classified (unsupervised) 3-4-7-8 composites were taken in the field. Also topographic map sheets of the Ghibe area and a GPS (Global Positioning System) were used in the field to ground-truth the image.

Ground-truthing and Ground Control Point (GCP) Data Collection

Ten days were spent in Ethiopia for the ground-truthing exercise. A total of 200 GCP's (Ground Control Points) were collected during that time. Ground control points are used to confirm the reflectance of different land use/land cover types as seen on the image. These points are also used check the accuracy of an interpretation, whether by hand or by computer software (supervised classification). There is limited access to much of the Ghibe area because only one main road connects the four study sites in the study area. It therefore takes some time to get from one site to another. To conserve travel time, half the time was spent in the adjacent Gullele/Gerangera study sites and half the time was spent near the Ghibe/Kumbi study sites.

A GCP data sheet was designed to match the datasheets used in earlier Ghibe land-use/land cover change analysis (Reid et al 1997, 2000) (see data sheet, Appendix II). At each GCP, date, time, GPS coordinates, photo number and bearing, land-use/land cover type and vegetation cover information and were recorded. These digital photographs now serve as permanent photo-points for future analysis of landscape change. Location data were recorded either by walking to the land-use/land cover type and marking the coordinates in the GPS (also recording these coordinates on the GCP data sheet), or by locating these areas on the printed image (with UTM grid, compass bearing and topo sheet). The land-use/land cover type was recorded directly on the image or to a data sheet. A note was also made whether or not the area had been recently burned. The land-use types recorded were separated into the following seven primary categories (see the category characteristics used in analysis above and in Figure 4) as used in previous studies:

- Wooded grassland
- Riparian woodland
- Cultivation
- State Farm
- Recent Fallow field
- Village
- Tukel

The GCP data sheet information and map drawn data were entered into EXCEL spreadsheets (Microsoft ® Excel 2000, 9.02720). The GCP location data were downloaded from the GPS using OziExplorer GPS Mapping Software (Version 3.90.3a). After verification of the GCP data, these files were converted into shape files (.shp) in ARCVIEW for use in interpretation and analysis *(see Appendix III for a list of filenames and descriptions).*

Land-use/Land Cover Interpretation and Change Analysis[1]

The goal of this study was to compare the land-use/land cover analysis conducted by Reid et al. at ILRI for 1993 to the current 2003 image. If possible, the 1997 image analysis would be included as well (see Reid et al., 2001). The 1993 image was classified for all four sites, however, the 1997 image was only classified for part of the Gullele site. Therefore this analysis only compared the classified 1993 image and the new 2003 image, both covering all four study sites. Reid et al., 2000 used data different platforms (aerial photographs and satellite imagery) to compare land-use change from 1953-1993. This team noted that there are difficulties in using different data types of different resolutions, because there is a danger that land-use/land-cover differences between time periods may result from differences in image interpretation (ability to discern land-use/land-cover types) rather than from actual changes taking place on the ground. Therefore to remain consistent interpretation for all dates, this team analysed all data by hand at a 1:50,000 scale. This same methodology was used to interpret the 2003 image to ensure comparability with the previous analysis. Interpretation of images by hand is much more time consuming, but potentially more accurate, than a supervised or unsupervised classification. All analysis was conducted using ARCVIEW GIS software.

Hand drawn classification

Identification of LU/LC types on the 2003, 3-4-7 composite image was accomplished using some of the GCP's, field experience, and calibration of interpretation with Robin Reid. Each of the four study sites was interpreted separately. A polygon was digitized around the area of each LU/LC type using ARCVIEW software. The GCP file was overlaid onto this composite to confirm interpretation as needed. A portion of the GCPs could be used for visual training of land-use/land-cover classification so that the other half would be available for checking the accuracy of the interpretation. As mentioned above, all interpretation was conducted at a 1:50,000 scale. The smallest interpretable resolution at this scale was 100 m x 100 m (1 hectare). A polygon (shapefile) was created for each of the digitized land use/land cover types.

[1] The following descriptions of the image analysis are given in full detail so that future analyses of land-use change in Ghibe Valley can be done quickly and accurately.

Riparian areas and upland woodland types have similar reflectance on the image. However, riparian areas by definition are near a watercourse. Therefore, the rivers were defined in a unique manner. The rivers of Ghibe were digitized previously from topographic maps. These files were used to create a riparian buffer zone of (3 pixels or approximately 100 m) on either side of the river course. This map was overlaid on the digitized riparian areas and those areas, which fell within this buffer, were included in the final riparian land cover map. The remaining upland woodlands were combined with the wooded grassland category.

A calculation of accuracy of the hand-interpretation was done by using 60 GCP's which were not used for visual training in the hand-interpretation. This test revealed that wooded grasslands were classified 77% of the time correctly, cultivated areas were classified 66% correctly and riparian woodlands were classified with 50% accuracy. Riparian woodlands were most definitely more accurately identified than this number reflects due to its unique signature; however, there were only a few GCP's of this type to run the accuracy analysis. (*Note: most of the GCP's (140) were used for the visual training of the hand-interpretation and these could not be used for the accuracy check also).*

Land-use/Land-cover Area Calculation and Change Analysis

When the hand interpretation for the 2003 image was completed, the land-use/land-cover ARCVIEW shape files (polygons) were converted to GRID (raster) format for analysis. Within each study site the raster files for all the land-use/land-cover types were combined to make a file, which contained all of the LU/LC types and their respective areas (number of pixels). The area of each land-use/land-cover type (in meters squared) was calculated by multiplying the number of pixels of that land-use/land-cover type by the cell length squared and multiplying this number by the total number of pixels in the study site.

$$\textit{Area of LU/LC type} = \frac{\textit{Number of pixels LU/LC type} \times (\textit{Cell size})^2}{\textit{Total Number of Pixels in Study Site}}$$

The percentage of area of each land-use/land-cover type is presented in Table 1(page 29).

The land-use/land-cover classification used in 1993 was compared to the 2003 interpretation (See Tables 1 and 2, and Appendix IV for changes in land-use/land-cover).

After locating the files that were used in the 1993 analysis they were checked for accuracy. It was noticed that the land-use/land cover polygons were offset by variable distances. It was determined that this offset was caused when the GRASS GIS files were converted into IDRISI GIS files during the previous analysis. These offsets were corrected (by Russ Kruska-ILRI) by rejoining the correct polygon files and recreating the final grid files for 1993 study sites. This should be noted for possible future use of the 1957, 1973 and 1987 data layers because they will have to be recreated as well to correct this offset.

Once these layers were corrected, they were analyzed further for each study site. In addition to the simple calculation of the absolute area of each land-use/land-cover type currently in each study site (mentioned above), a cross tabulation of the percent change over time was performed. A cross tabulation or a transition matrix determines the likelihood that a pixel of one land-use/land-cover type changes (converts) into another land-use/land-cover type or remains the same land-use/land-cover type over time. This analysis was done using ARCVIEW analysis called, appropriately, 'Tabulate'. Basically, the grid file for the 1993 data was cross-tabulated with the 2003 grid file. This change is presented as the *absolute* or *relative* change in area (expressed as a percentage) of each LU/LC type in 2003.

Absolute Percent Change:

The absolute percent change is the percentage **of the entire study site** that changed from one land use type to another between 1993 and 2003. This gives a sense of the absolute amount of land moving from one land use type to another over time and also provides a measure of the proportion of each study site existing in each land-use type in 1993 and 2003 (and thus the composition of the landscape). For example, of the entire Gullele area, 1.223% of entire landscape change from 1993 to 2003 was a conversion of riparian woodland to wooded grassland.

Relative Percent Change:

The relative percent change is the percentage **of individual land-use types** that changed from one land-use type to another between 1993 and 2003. This measure gives a sense of the comparative rate of change in different land-use types over time so that relative rates of gain or loss of land-use types with very different areas can be compared to each other. For example, even though only a very small percentage (1.22%, see above) of the entire landscape change between 1993 and 2003 was a conversion of riparian woodland to wooded grassland, this represented a 30% change in the total amount of riparian woodland existing on the landscape in 1993 (Table 2, page 32)).

Results

Land-use/Land-cover Composition of Each Study Site in 1993 and 2003

Figures 5-8 and Appendix IV show maps of four study sites in 1993 and 2003. The land-use/land-cover composition is shown in pie charts for each year. Below is a summary of the composition of the landscape in 1993 and 2003 in each of these sites.

Gullele

In 1993, the Gullele study site was predominantly wooded grassland (79%) with only 17% in cultivation and 4% in riparian woodland (Figure 5). Currently this area has shifted to a predominantly cultivated landscape (56%) with wooded grassland (39%), primarily in the southeast corner of the site, and 5% in riparian woodland.

Gerangera

Further south of Gullele is the Gerangera site, where landscape has followed the same trend but to a lesser extent (Figure 6). This area in 1993 was dominated by wooded grassland (85%) and currently has 39% in this land cover type. Smallholder farms only covered 10% of the landscape in 1993, growing to 25% cover in 2003. As with the other sites, the coverage of riparian woodlands areas remained low at 6%.

Ghibe

Ghibe area is the smallest of the four study sites within Ghibe (Figure 7). It was dominated by wooded grassland in 1993 (91%) and remained so in 2003 (86%). Smallholder farms cover little of this landscape with just over 3% cover in 1993 and 9% in 2003. Riparian woodlands also are rare in the Ghibe site with 6% cover in 1993 and 5% cover in 2003.

Kumbi

South of Gerangera is Kumbi study site (Figure 8). Similar to other sites, Kumbi was dominated by wooded grassland (74%) in 1993. Currently wooded grassland and cultivation are of equal area (47% each). The amount of riparian woodland increased from 3% to 6% of the area over this time period.

Figure 5. Land use and land cover in the Gullele study site in 1993 and 2003. Pie charts show the percent composition of each land-use/land-cover type for each year.

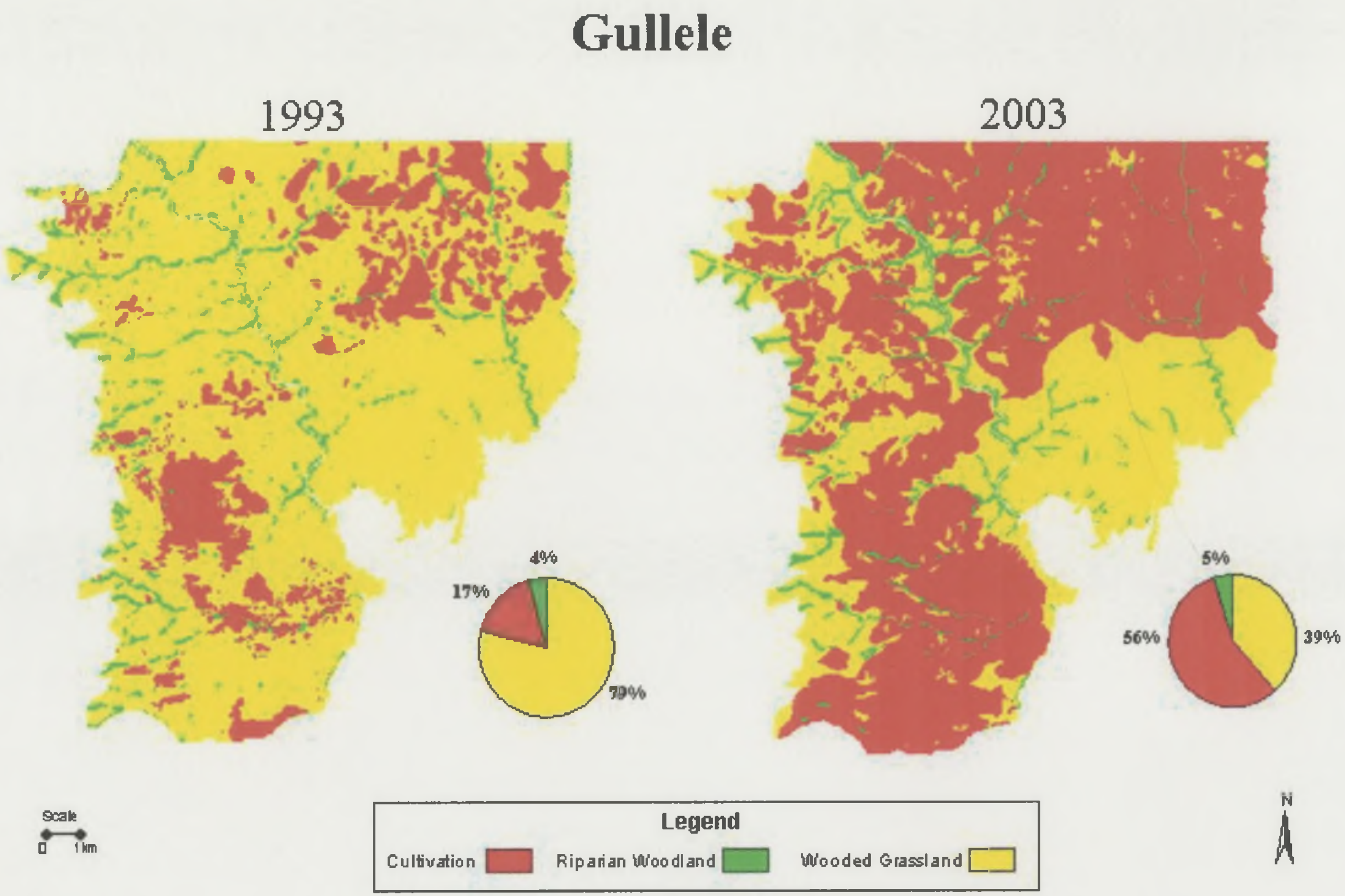


Figure 6. Land use and land cover in the Gerangera study site in 1993 and 2003. Pie charts show the percent composition of each land-use/land-cover type for each year.

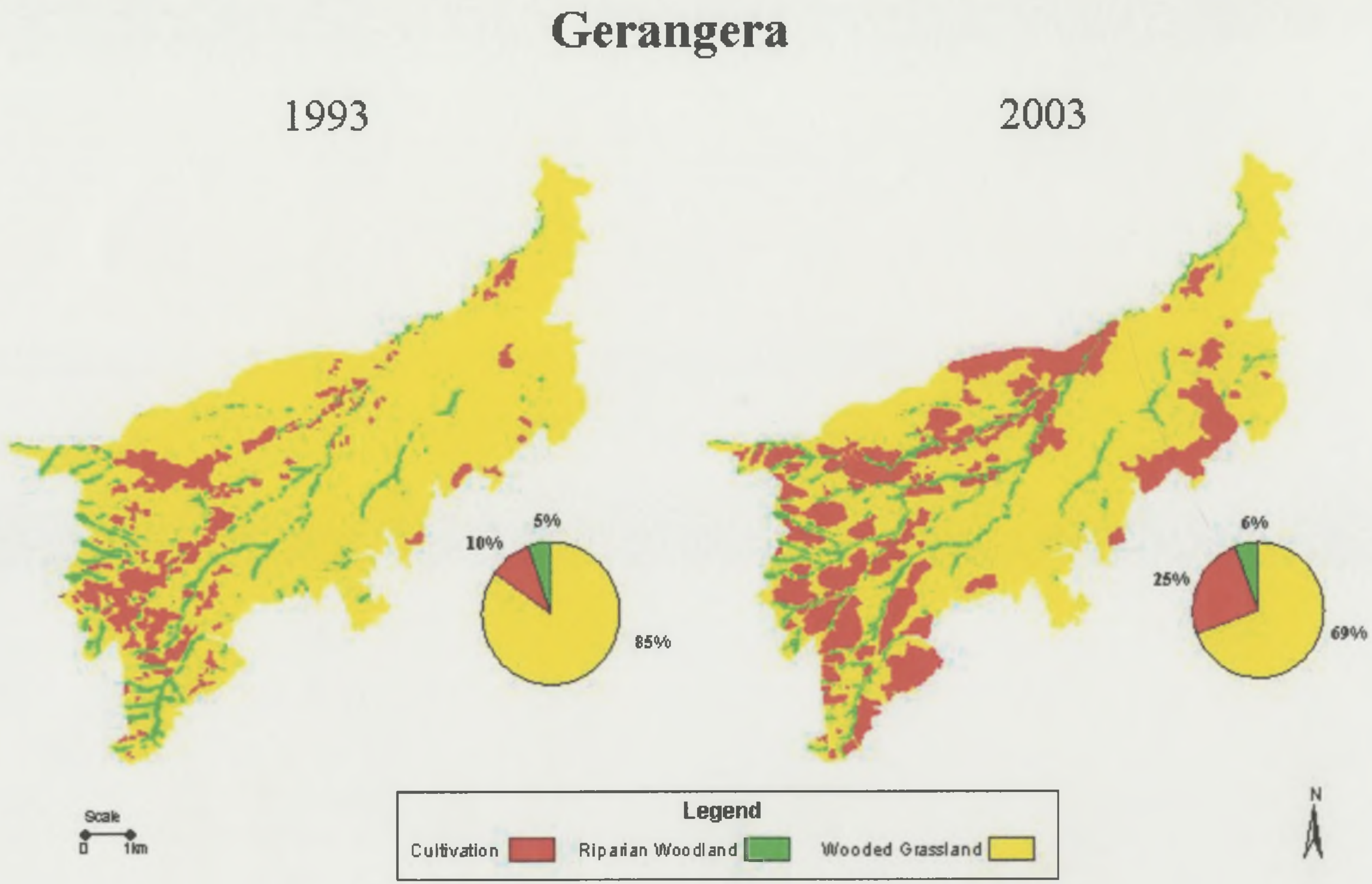


Figure 7. Land use and land cover in the Ghibe study site in 1993 and 2003. Pie charts show the percent composition of each land-use/land-cover type for each year.
(Note that the state farm was excluded from the pie chart so that direct comparisons could be made to the three other sites).

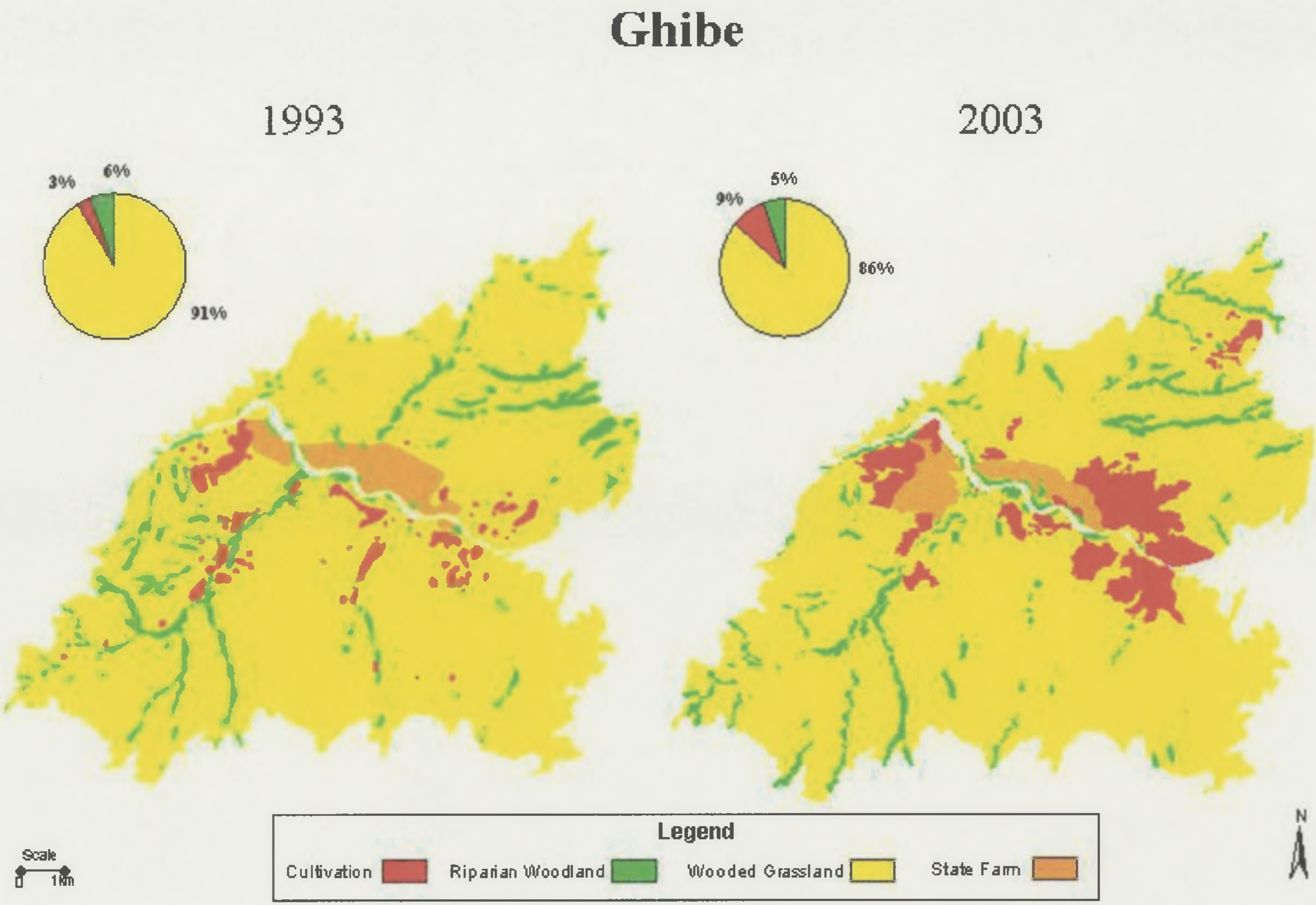
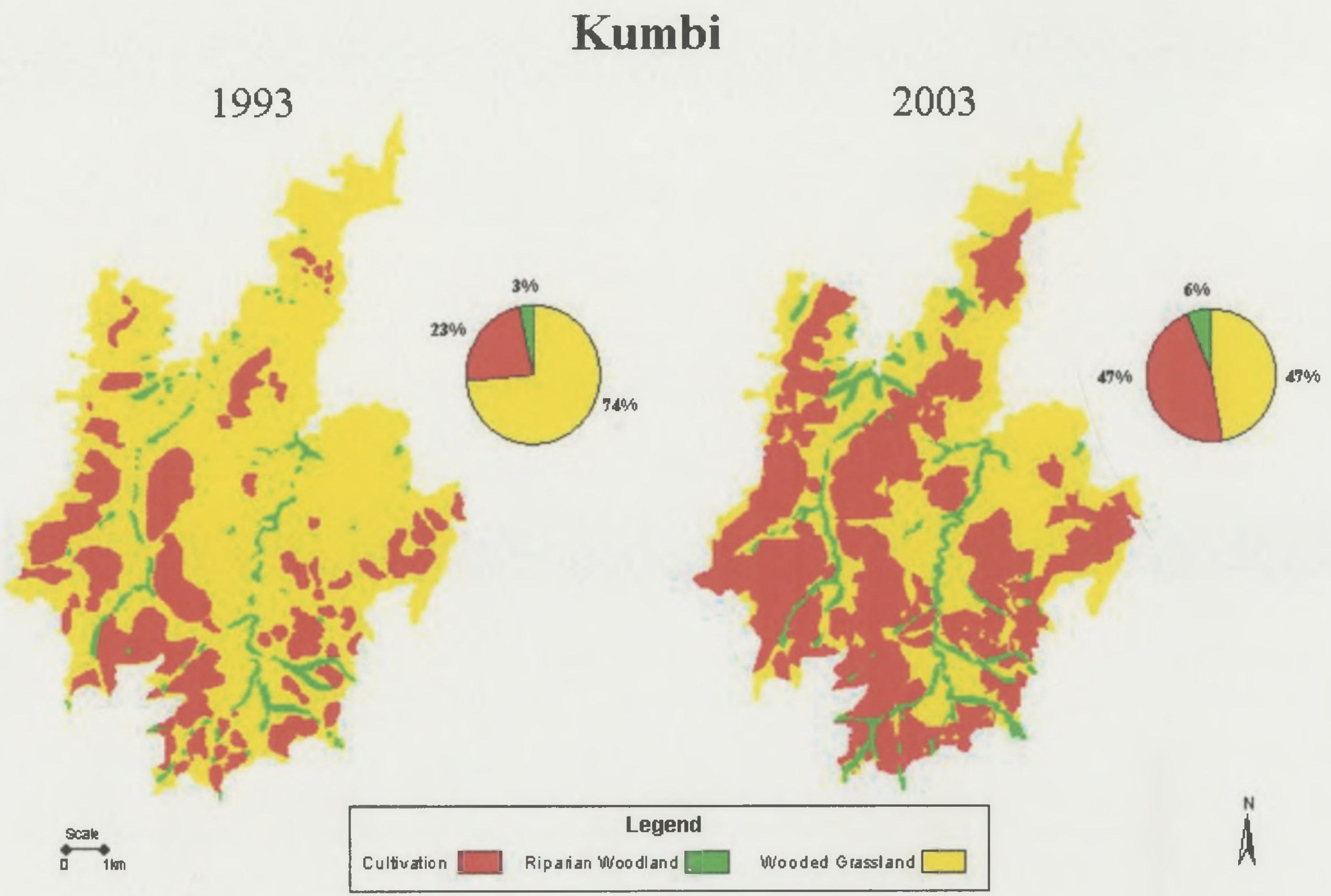


Figure 8. Land use and land cover in the Kumbi study site in 1993 and 2003. Pie charts show the percent composition of each land-use/land-cover type for each year.



Land-use/Land Cover Change: 1993-2003

The results of the LU/LC change analysis for 1993 to 2003 are profound (Figures 5-8, Appendix IVa-d). There was a considerable increase in the amount of area cultivated in all four sites (Figures 9-10-). The rate of increase ranged from 101-232%. The Gullele study site, where tsetse control has been most successful, changed the most (232% increase in cultivated area). In the Ghibe study site, the area of cultivation is small (currently 9%), however, it had the second highest rate of increase in cultivation at 182%. Gerangera saw a 147% increase in cultivation over this 10-year period and the Kumbi area a 101% increase in cultivation.

The percent area of all land-use/land-cover categories for 2003 are included in Table 1 along with the results for 1957-1993 for comparison (1957-1993 data from Reid et al. 2000). The earlier data are presented for comparison to the current composition in Ghibe. The percentages for 1993 and 2003 data are highlighted because they are the focus of the current study. The general trends for all study sites in 2003 show an increase in cultivation, a loss of wooded grasslands and little or no change in riparian woodlands. Also, throughout the study area there is a shift from riparian woodland into wooded grassland. This may indicate that the riparian woodlands are becoming degraded and transforming into wooded grassland (see Discussion section). For an in-depth discussion of the land-use/land-cover changes between 1957 and 1993 see Reid et al., 2000).

Figure 9. Relative rate of change in cultivated area in each study site of Ghibe Valley between 1993 and 2003.

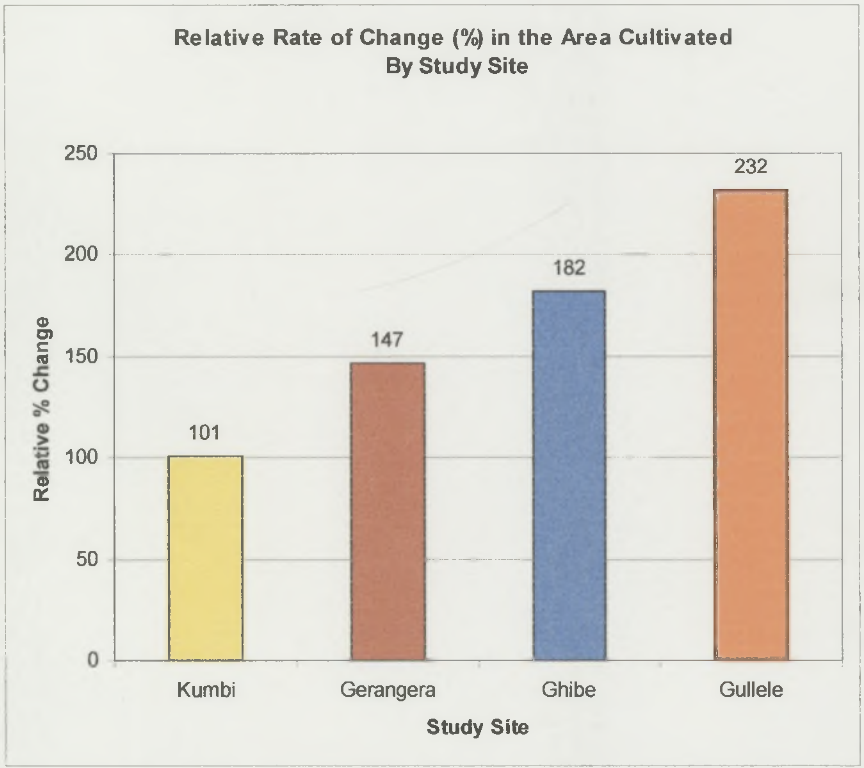


Figure 10. Absolute percentage of the land cultivated from 1957-2003 at the four Ghibe Valley study sites.

Note that the Reid et al. (2000) did not create land use maps for the Ghibe site for 1957, 1973 and 1987. Time line at the bottom indicates that time is variable between the study years which were analyzed.

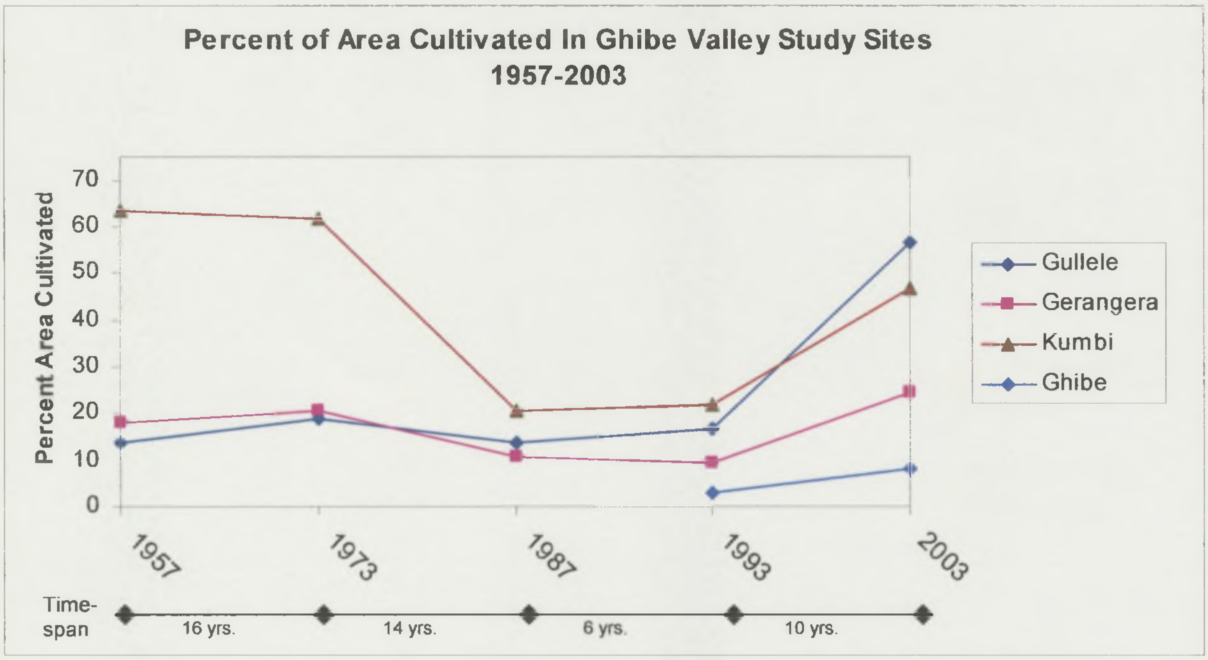


Table 1. Percent composition of the area of land in different land-use and land-cover types in the four study sites from 1957 to 2003 (1957-1993 data from Reid et al. 2000) including the Ghibe study site in 2003.

Note that the data for 1993 and 2003 are in bold because those years were analyzed in this study. The large-holder cultivation in 2003 was only in the state farm areas of Ghibe. The total area of Kumbi is 59 km², Gerangera is 119 km², Gullele is 293 km², and Ghibe is 109 km² (Wilson et al. 1997). Note that Ghibe study site was not analyzed 1957-1987 (NT=not taken). Below the percentage area is the area in km².

		Year				
Land-use/Land-cover type	**Site**	***1957***	***1973***	***1987***	***1993***	***2003***
Wooded grassland	Kumbi	34.1 *20.1 km²*	34.8 *20.5 km²*	75.0 *44.3 km²*	**73.5** ***43.3 km²***	**47.3** ***27.9 km²***
	Gerangera	75.4 *89.7 km²*	73.9 *87.9 km²*	83.8 *99.7 km²*	**84.8** ***100.9 km²***	**69.5** ***82.7km²***
	Gullele	81.0 *237.3 km²*	73.0 *213.9 km²*	80.3 *235.3 km²*	**78.9** ***231.2 km²***	**38.6** ***113.1 km²***
	Ghibe	NT	NT	NT	**91.0** ***99.2 km²***	**83.5** ***91.0 km²***
Riparian woodland	Kumbi	2.6 *1.5 km²*	3.5 *2.1 km²*	4.5 *2.7 km²*	**3.4** ***2.0 km²***	**6.2** ***3.7 km²***
	Gerangera	6.8 *40.6 km²*	5.5 *41.4 km²*	5.6 *89.3 km²*	**5.3** ***87.5 km²***	**6.0** ***56.3 km²***
	Gullele	5.2 *15.2 km²*	7.4 *21.7 km²*	5.9 *17.3 km²*	**4.1** ***12.0 km²***	**4.6** ***13.5 km²***
	Ghibe	NT	NT	NT	**5.46** ***5.4 km²***	**5.1** ***5.1 km²***
Smallholder cultivation	Kumbi	63.3 *37.3 km²*	61.7 *36.4 km²*	20.5 *12.1 km²*	**23.1** ***13.6 km²***	**46.6** ***27.5 km²***
	Gerangera	17.8 *21.2 km²*	20.6 *24.5 km²*	10.6 *12.6 km²*	**9.95** ***11.8 km²***	**24.6** ***29.3 km²***
	Gullele	13.8 *40.4 km²*	19.0 *55.7 km²*	13.8 *40.4 km²*	**17.0** ***49.8 km²***	**56.5** ***165.5 km²***
	Ghibe	NT	NT	NT	**2.95** ***3.2 km²***	**8.6** ***9.4 km²***
Largeholder cultivation	Kumbi	0	0	0	**0**	**0**
	Gerangera	0	0	0	**0**	**0**
	Gullele	0	0.6 *1.8 km²*	0	**0**	**0**
	Ghibe	NT	NT	NT	**3.5** ***3.8 km²***	**3.2** ***3.5 km²***

The transition matrix tables (Table 2a-d) give a detailed picture of how individual land cover classes changed over time, showing the destiny of each of the pixels on the Ghibe landscape between 1993 and 2003. These changes can also be seen in the maps of Appendix IVa-d. This table includes absolute percent of change in any one LU/LC type, based on the entire study site area. It also contains the relative percent change (in parentheses) based only on the area for each LU/LC type.

At Gullele, cultivation was very stable over time (91% showing no change), while about half of all wooded grasslands and riparian woodlands converted to a different land-use type (Table 2a). Most of the wooded grassland (51%) was cleared by farmers and cultivated, and little (3%) became riparian woodland. By contrast, a third of riparian woodlands reverted to wooded grassland, and 18% was cleared for farming. . Thus, farmers preferred to clear wooded grassland rather than riparian woodlands for farming. The shift of riparian woodland to grassland may indicate a degradation of these woodlands as they are used more intensively by wood collectors and by herders for livestock grazing..

In Ghibe the results are somewhat different (Table 2b). Here, wooded grasslands were most stable and the riparian forests were the least stable over time. The highest relative percent change occurred where 66% riparian woodland in 1993 was converted to wooded grassland. Even though the general, (absolute) trends show an increase in cultivation, farmers let 51% of their fields go fallow and convert to wooded grassland by 2003.

Similar to Ghibe, grasslands changed the least at Gerangera, while riparian woodlands changed the most. Almost half of the riparian woodland shifted into wooded grassland (Table 2c) although 44% of the riparian areas remained unchanged. Like Gullele, farmers preferred to clear grasslands for cultivation rather than riparian woodlands.

The Kumbi area remained more stable than the other three study sites (Table 2d). Compared to the other three sites, riparian woodlands were remarkably stable at Kumbi. Similar to Gerangera, the main change was in a conversion of the wooded grasslands to cultivation (38%), although much of these grasslands (57%) did not change over time. A small portion of the area that was cultivated in 1993 was left fallow and converted to wooded grassland

(16%) and riparian habitat (2%). There was also conversion of riparian woodland to wooded grassland (26%).

In summary across the sites, farmers clearly preferred to clear wooded grasslands for cultivation rather than riparian woodlands. However, in all sites, but particularly Ghibe and Gerangera, there seems to be significant loss of riparian forests, potentially for fuel wood and construction and lack of regeneration caused by increased livestock grazing. Particularly in Ghibe, farmers abandoned many of their fields, leaving them to go fallow between 1993 and 2003.

Table 2. Transition matrix for the absolute and relative (in parentheses) percent LU/LC change from 1993 to 2003 in the study sites of Ghibe Valley.

In Gullele the area used in Eucalyptus plantation (<1%) in 2003 was not included in this table as it was not identified in the 1993 interpretation). Note: the absolute percentages add up to 100% over the total area, the relative percentages (in parentheses) are totaled for each LU/LC type. Whether the change is considered to be one of ecological conversion, no change or recovery is noted above the percentages

2a. Gullele	*2003*			
1993	**Wooded Grassland**	**Cultivation**	**Riparian Woodland**	**Total**
Wooded Grassland	No Change 35.8 (45.4)	Conversion 40.3 (51.0)	Recovery 2.3 (2.9)	(100%)
Cultivation	Recovery 1.3 (7.7)	No Change 15.5 (91.0)	Recovery 0.2 (1.28)	(100%)
Riparian Woodland	Conversion 1.22 (30.1)	Conversion 0.75 (18.4)	No Change 2.09 (51.5)	(100%)

2b. Ghibe	*2003*				
1993	**Wooded Grassland**	**Cultivation**	**Riparian Woodland**	**State Farm**	**Total**
Wooded Grassland	No Change 77.8 (88.3)	Conversion 6.1 (6.9)	Recovery 3.1 (3.5)	Conversion 1.2 (1.3)	(100%)
Cultivation	Recovery 1.2 (51.2)	No Change 1.4 (46.4)	Recovery 0.06 (1.9)	No Change 0.01 (0.5)	(100%)
Riparian Woodland	Conversion 3.6 (66.0)	Conversion 0.1 (1.4)	No Change 1.7 (31.8)	Conversion 0.04 (0.7)	(100%)
State Farm	Recovery 0.6 (17.0)	No Change 1.9 (23.5)	Recovery 0.2 (5.2)	No Change 1.9 (54.3)	(100%)

Table 2. Continued...

2c. Gerangera	*2003*			
1993	**Wooded Grassland**	**Cultivation**	**Riparian Woodland**	**Total**
Wooded Grassland	No Change 64.3 (75.8)	Conversion 17.4 (20.5)	Recovery 3.1 (3.7)	(100%)
Cultivation	Recovery 2.6 (26.0)	No Change 6.8 (68.2)	Recovery 0.6 (5.8)	(100%)
Riparian Woodland	Conversion 2.6 (49.4)	Conversion 0.4 (6.9)	No Change 2.3 (43.7)	(100%)

2d. Kumbi	*2003*			
1993	**Wooded Grassland**	**Cultivation**	**Riparian Woodland**	**Total**
Wooded Grassland	No Change 42.1 (57.2)	Conversion 27.7 (37.7)	Recovery 3.7 (5.0)	(100%)
Cultivation	Recovery 3.6 (15.5)	No Change 19.1 (82.6)	Recovery 0.4 (1.9)	(100%)
Riparian Woodland	Conversion 0.9 (26.2)	Conversion 0.4 (12.0)	No Change 2.1 (61.8)	(100%)

Discussion

Interpretation of Results

Land-use/Land-cover Changes in Ghibe Valley 1993-2003

Additional evidence of the impacts of tsetse control on land use comes from socio-economic studies conducted in Ghibe Valley over the last decade. Farmers in areas with low trypanosomosis incidence (Gullele) were able to plough 50% more land than farmers in areas with high trypanosomosis incidence (Ghibe; Swallow, et al. 1998). Also, farmers hold more adult cattle and goats in areas with than without tsetse control.

In the early 1990's (Reid et al. 2000) farmers recognized that if the tsetse fly was controlled there would be increased migration into Ghibe Valley causing further agricultural expansion. At first glance, the results here strongly support this observation by farmers. The greatest expansion (232%) of cultivation occurred in Gullele, where tsetse has been most successfully controlled over the last decade. Thus it seems that tsetse control may have 'pulled' farmers into the valley. However, there have been other factors (see Figure 11) that have also 'pushed' people away from other areas of Ethiopia to Ghibe, like translocation due to drought in northern Ethiopia or land shortages in other parts of the country (Reid et al. 2000). Therefore, it is unclear how important the 'pull' of tsetse control was in attracting migrants compared with the 'push' of other factors. The relative importance of these push and pull factors can only be quantified through socio-economic and land-use surveys with farmers in the valley and consultation with Wereda records (see *Suggestions for Further Studies* section below).

The speed of land-use change in Gullele was unusual. If tsetse control had a major role at this site, the change itself may have accelerated the control of the tsetse fly as well. There is come evidence (Jordan 1986, Reid et al. 2000b) that some species of tsetse fly are particularly sensitive to land clearing and habitat change. The fly in the Ghibe Valley that is most effective in transmitting trypanosomosis is *G. morsitans* and this species is also the most sensitive to changes in its preferred savanna habitat (Jordan 1986). It may be that control of the fly partly initiated the change in land use, and over time, changes in land use further suppressed populations of the fly.

One could also hypothesize that the Gullele area had such a large increase in cultivation because of its fertile soil, good road access or proximity to a market. However, Kumbi (101% increase in cultivation) is closer to a market and a major road (the road to Jimma) and has similar soil. The Ghibe site is on a major road, has similar market access, but has poorer soils than Gullele. It is only Gerangera that is far from a main road and has only moderate access to a market compared with Gullele. Despite these disadvantages at Gerangera, land-use change was particularly fast here, second only to that in Gullele. Further group and household interviews are required to disentangle the causes of the rapid land-use changes in the Ghibe Valley.

The area of Gullele (southeastern corner) that shows mostly wooded grassland was largely cultivated in the mid-1990's by largeholder investors using tractors. This area has been left fallow for at least 6 years now and is converting back to wooded grassland. There were people cultivating in this area before the investors arrived and it is likely that the people will move back to cultivate this area as the land available further north in Gullele becomes more scarce. This is the only large wooded grassland in the Gullele area, even though many of the trees were removed about a decade ago when the investors arrived. It is therefore anticipated that smallholder cultivation will expand to this area and there will be little wooded grassland remaining in the coming decade.

Although the overall area of riparian woodland did not change much over the last decade, there was some conversion of riparian woodland to wooded grassland (30-66%). This decrease in the canopy cover of the riparian areas could be caused by rapid drying of the climate or catatrophic physical events (very severe fires, landslides), but it is more likely that the expansion of cultivation has been accompanied by increased wood collection for building, charcoal production, and fuel wood.

Figure 11. Probable Causes and Ecological Consequences of Land Use/Cover Change in Ghibe Valley.

(Derived from: Reid et al, 2000)

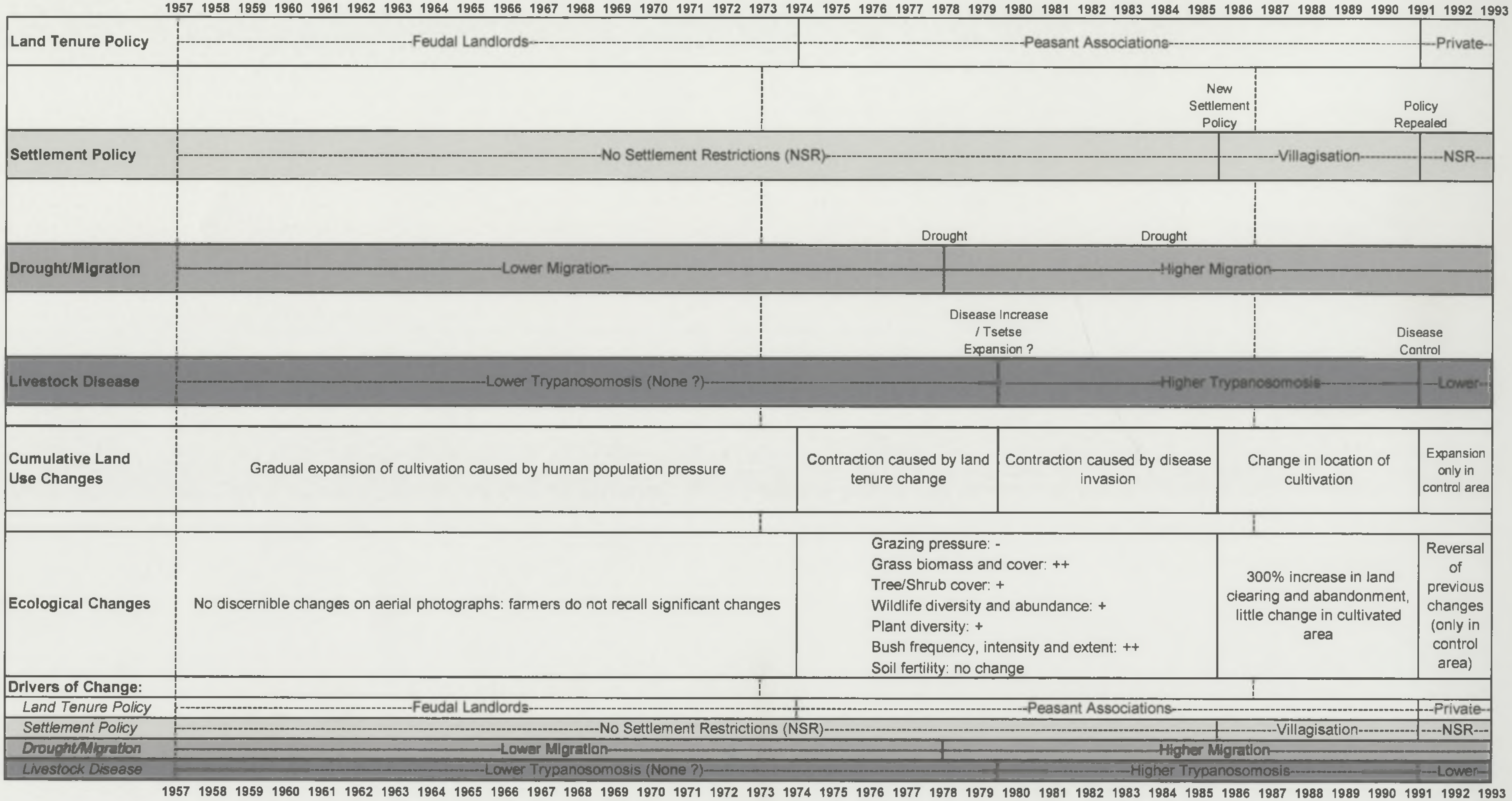
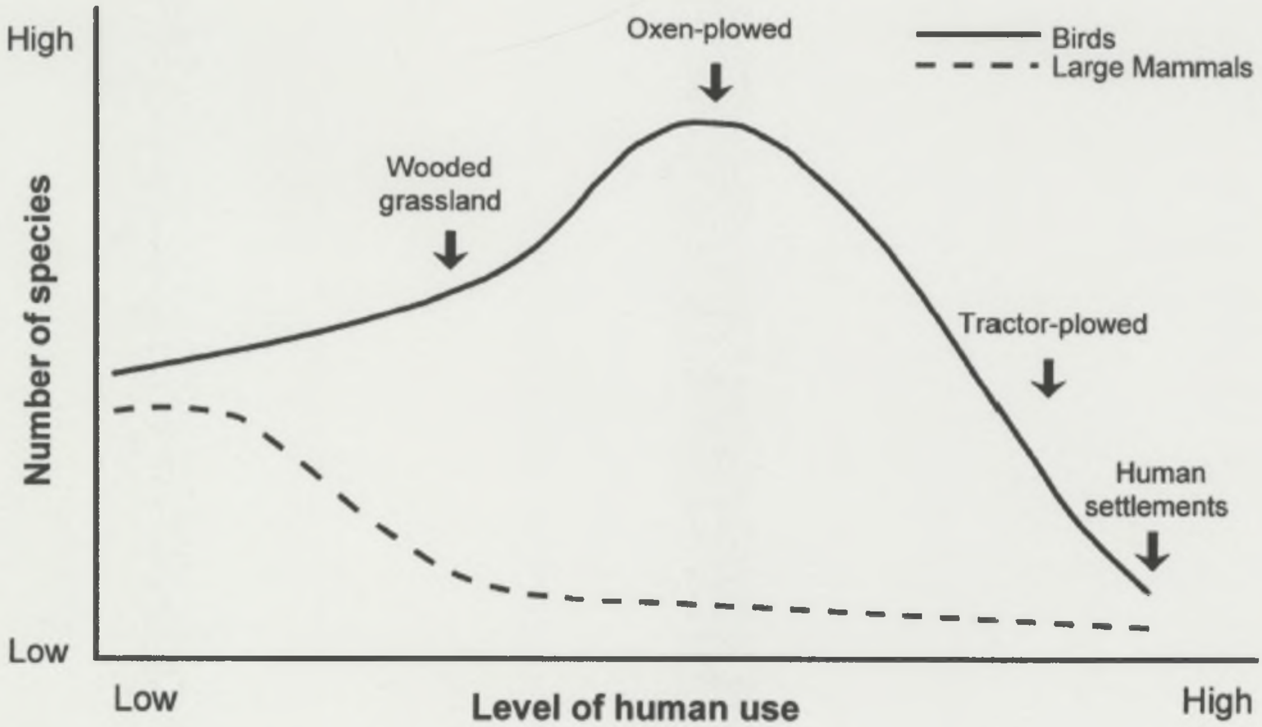


Figure 12. Effects of human-use intensity on the number of bird species (actual data) and large mammal species (hypothetical) in Ghibe Valley, Ethiopia.

(From Wilson et al., 1997).



Comparison of the effects of tsetse control in Ghibe to others areas of Africa

Some of the following is adapted from Reid (1999):

Over the last century, tsetse control officers have observed that people move away from tsetse belts or move away when their settlements become infested. The latter was observed in southwest Ethiopia in the late 1800's caused by a combination of rinderpest and trypanosomosis (Turton 1988). Kalu (1991) observed an exodus of farmers during a reinvasion of the Jos plateau in Nigeria in 1987. In northeastern Tanzania, a succession of famines resulted in partial depopulation of villages. Formerly cultivated fields became revegetated with bush and the fly reinfested the area. Once settled areas became reinfested, farmers felt compelled to move altogether (Ford 1971, Giblin 1990). Swynnerton (1936) observed that eradication of tsetse in Tanzania resulted in massive influx of people and subsequent over-use of the land.

Other observers described how settled people controlled contact with *Glossina* in pre-colonial times by burning bush late in the growing season, living in dense settlements that were largely free of the fly, and leaving the rest of the land infested (Ford 1971, Giblin 1990). Similarly, pastoralists used the land in ways that avoided tsetse either seasonally or altogether. They did (and still do) this by limiting movement of cattle through tsetse zones to the dry season when tsetse are most restricted in distribution (Jordan 1986, Dransfield et al. 1991, Roderick, Stevenson, & Oloo 1997).

More recent statistical analyses generally demonstrate that livestock populations, human populations and land-use are lower in areas infested with tsetse compared to tsetse-free areas. Bourn (1978) and Jahnke et al. (1988) found that cattle populations and TLU's (tropical livestock units) were depressed in tsetse-infested compared to tsetse-free areas within the same rainfall zones. Reid et al. (1995) used national GIS databases and statistical modelling to show that crop-use intensity was lower in tsetse-infested than tsetse-free in Zambia, but the opposite was true for Burkina Faso and Mali. These results imply that trypanosomosis may serve as a stronger constraint on land-use in some countries than in others. For Nigeria, Rogers et al. (1996) showed that cattle population densities are much lower in areas infested with the tsetse species, *Glossina morsitans*, than in areas that are tsetse-free. The speed of agricultural expansion, as measured by the intrinsic rate of increase, was faster in areas that had been cleared of tsetse than in infested areas.

Remote sensing studies like this one show varying impacts of tsetse control on land-use and land cover. The first remote sensing study of disease control impacts was conducted by Bourn (1983) in Lafia District, Nigeria, where he compared human populations, cattle populations and cropped area in areas with and without tsetse over time. He showed that the area of land cultivated and cattle populations grew marginally faster over time in the area with tsetse than the area without tsetse.

A number of studies found that tsetse/trypanosomosis control may accelerate land-use change, but it is neither the only nor the most important factor that encourages the expansion of cultivation. In northern and central Côte d'Ivoire, human population growth appeared to be more important than tsetse/trypanosomosis control in causing land-use change (Erdelen et al. 1994, Erdelen, Nagel & Peveling 1994, Nagel 1994). Pender, Mills and Rosenberg (1997), in a detailed study of the mid-Zambezi Valley, conclude that 'there is little evidence of a direct relationship between patterns of HDLU (human-dominated land use) change and either tsetse control operations or changes in livestock numbers and composition' (p.1). Similarly, in Kanyati Communal Land in Zimbabwe, farmland expanded from 0 – 30% cover between 1984 and 1993 despite continued presence of low populations of tsetse (Wangui et al. 1997). In Busia District, Kenya, Rutto (1997) found that agriculture expanded 3.2% per annum between 1961 to 1997, during a period when *G. fuscipes fuscipes* and *G. pallidipes* were present but at low levels. Similarly, Bourn and Wilson (1997) and Oloo (1997) show strong changes in land cover on Galana Ranch and Nguruman, Kenya between the 1950's and 1980's, but these changes appear to be caused by changes in elephant populations, livestock populations, bushfire frequency, firewood collection and climate, not by changes in trypanosomosis. Since the 1940's, human populations and the area cultivated have grown exponentially in Lambwe Valley, Kenya, despite the continued presence of *G. pallidipes* (Muriuki 1997).

These studies also measured the effects of changes in land-use on different types of land cover, which shows where farmers and pastoralists prefer to clear the land for cropping and where they prefer to graze livestock. Farmers choose either mixed or *Julbernardia globifora* woodlands over mopane and *Combretum* woodlands for cultivation, settlement, and grazing in the mid-Zambezi Valley, Zimbabwe (calculated from data in Pender, Mills and Rosenberg 1997). Farmers in Kanyati Communal Land, northwestern Zimbabwe, preferred open areas (vlei, bushland, and vlei edge) over miombo woodland for both cropping and grazing (Wangui et al. 1997). On Galana ranch, Kenya, growth in human populations caused a strong expansion of grassland habitats at the expense of woodland, presumably because of greater wood use (Bourn and Wilson 1997). In Cote d'Ivoire, farmers used gallery forests along water courses more frequently for agriculture than open savanna habitats between the 1950's and the 1990's (Nagel 1994, Edelen et al. 1994). Similarly, livestock use of riverine forests increased when tsetse were eradicated in Somalia (Hanks & Hogg 1992). In Busia District, Kenya, Rutto (1997) found that riparian forest and dense woodland all but disappeared between 1961 and 1997; these areas were converted into cropped fields. Similarly, agriculturalists in Ghibe Valley, Ethiopia, converted riparian forest areas into cultivation more often than open grasslands between 1973 and 1987 (Reid et al. 1997). Muriuki (1997) shows nearly a complete loss of riparian forest and a partial loss of dense woodland to cultivation between 1948 and 1993 in Lambwe Valley, Kenya.

Further evidence of the land-use impacts of tsetse control comes from household interviews. The strongest evidence of this type of the effects of trypanosomosis on land-use comes from Ethiopia (Kriesel & Lemma 1989, Slingenburgh 1992, Swallow in progress, Reid et al. 1997, Reid et al. submitted) and Burkina Faso (Kamuanga et al. 1997). During 63 household interviews, farmers claimed that a recent increase in disease severity caused strong losses in cattle populations, cultivated field areas and milk production in Didessa Valley, Ethiopia (Kriesel & Lemma 1989, Slingenburgh 1992) similar to losses in nearby Ghibe Valley (Reid et al. 1997).

These studies also highlight the effects of trypanosomosis on livestock populations and human migration. In The Gambia, farmers have larger herds of cattle in areas with a moderate risk of trypanosomosis than in areas with high risk of trypanosomosis (Mugalla et al. 1997). In Somalia, tsetse eradication had no apparent effect on the use of draught power by farmers (Hanks and Hogg 1992). In southwestern Burkina Faso, farmers used oxen for ploughing more frequently after tsetse/trypanosomosis control than before control (Kamuanga et al. 1997). Finally, tsetse control does seem to attract human migrants in northwestern Zimbabwe (unpublished data, Govereh & Swallow) but not in southwestern Burkina Faso (CIRDES/ITC/ILRI 1997).

In summary, the impacts of tsetse control and changes in land use are strong, like Ghibe Valley; in others it is only one of several factors affecting land-use. The current study is the strongest example of the tsetse control impacts found to date in Africa.

Potential impacts of land-use change on the environment in Ghibe Valley

As mentioned in Wilson et al. (1997) and Reid et al. (2000), the riparian woodlands of Ghibe Valley are extremely species rich and very important to the biodiversity of the ecosystem. The canopy cover and roots of the riparian woodland also prevent soil erosion and sedimentation along river courses. These woodlands form an important resource supporting the livelihoods of Ghibe farmers and the lives of many of the valley's diverse organisms.

Wilson et al. (1997) suggested that the intensity of cultivation present in 1993/94 was at an 'intermediate' level and thus had not yet strongly affected biodiversity in the Ghibe Valley. They also predicted that further expansion of cultivation, particularly in riparian areas, would lead to biodiversity loss (Figure 12), similar to the intermediate disturbance hypothesis of Connell (1978). This study shows, especially in the Gullele area, there has been a huge increase in density of smallholder farms. As this density increases the number of trees/hedgerows are reduced and the landscape begins to resemble that of largeholder tractor-ploughed fields, which were found to be species poor by Wilson et al. (1997). It is very important to learn what crop types, densities of fields and farming practices both most enrich and impoverish agro-ecosystems. Knowing this point can help farmers, pastoralists and other land-use managers to better sustain farming systems when faced with the current rapid changes in socio-political and climate across Africa. Some suggestions for further study follow.

Suggestions for further studies in Ghibe and elsewhere

Biodiversity Monitoring

Continued monitoring of the biodiversity at Ghibe and other tsetse control sites in Africa is extremely important in understanding the effects of tsetse control and more general agricultural development efforts (Reid et al., 1999). The following taxonomic groups have been studied previously at Ghibe and should be surveyed again in the near future.

Vegetation:

Previously assess by Reid et al. of ILRI in 1993/4 (Reid et al., 1997). In this study the vegetation structure and tree species composition were assessed using the same 250 m x 250 m and 60 m x 100m plots used by Wilson et al. in the bird diversity study, see below. Percent cover and height of herbaceous plants were recorded in each plot and shrubs and trees were measured using Bitterlich angle gauge (Bitterlich 1984). For additional details see Reid et al., 1997.

Birds:

Initially, C. Wilson conducted bird diversity surveys in Ghibe in 1993/4 (Wilson et al., 1997). Study plots were selected using a land-use/land cover map derived from a TM-7 image (1993). In each land use/land cover type in each of the 4 study sites, five 250 m x 250 m or 60 m x 1000 m (riparian) plots were assessed for a total of 70 plots. The method used for bird species diversity estimates was the timed-species count derived from Pomeroy and Tengecho (1986). For additional details see Wilson et al., 1997.

Butterflies/other insects:

Gardiner and Reid have collected insect data at Ghibe and other tsetse control sites throughout Africa (Reid et al., 1999). At Ghibe, butterflies were collected using walking counts and net traps. New species of butterflies were identified in the valley and range extensions of existing species were made. See Reid et al., (1999) and Gardiner and Reid (1999) for further details of these studies.

Wildlife:

Farmer interviews were used to assess the presence/absence of large mammals in the Ghibe Valley by Reid et al. (1996). They also recorded approximately when and probable reasons why wildlife populations declined in the area from these interviews. These studies were very qualitative in nature and thus need to be improved with more quantitative studies. All the biodiversity work could also be strengthened by conducting interviews of the perceptions of change in biodiversity that is important to people.

In addition to large mammal studies it is recommended by this consultant that the Abyssinian Colobus monkey (*Colobus guereza*) population in the valley be assessed. This species of primate requires healthy riparian habitat to survive and therefore could be an indicator species the health of the riparian ecosystem.

Other indicators of ecosystem health

The ILRI environmental impacts team did not measure other indicators of ecosystem health in Ghibe Valley. Other important variables could be identified by community members for monitoring and simple indicators of change could be developed for long-term, local monitoring. For example, soil structure, erosion, fertility and nutrient cycling rates could be monitored to assess any degradation processes. Effects of pour-ons on aquatic insects and dung beetles may also be important measures.

Socio-Economic Surveys

In 1992, Swallow et al conducted 'semi-structured' group interviews of about 50 cattle owners who had received tsetse control treatments and 166 household interviews in the Gullele study site (Swallow et al.,1995). Socio-economic information as well as factors affecting demand for tsetse treatment of livestock were derived from these interviews Data were collected through group interviews.

In addition to repeating these surveys, population census information for 1993-present should be compiled for the study area (at least at the Wereda level) and entered into a GIS.

Land-use/Land Cover Change Farmer Surveys

Additional farmer surveys were conducted by Reid et al. in 1996/7 to assess the attitudes and historical changes in land-use/land cover over the past century. Through these interviews this team was able to make strong guesses of the reasons behind some of the land-use change patterns seen in the analysis of change between 1957 and 1993 in the Ghibe Valley by relating them to villagization, land tenure, government policy and climatic factors. See Reid et al., 2000 for further details of these interviews.

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Appendix 1. Terms of reference for this project.

5 March – 28 March 2003 inclusive:

- Acquire and prepare 1993 data and new TM-7 satellite image for Ghibe Valley, Ethiopia.
- Prepare datasheets and field sampling equipment.
- Ground verification and ground truth point (GCP) collection in Ethiopia.

8 April – 26 April 2003:

- Hand-interpret/classify 2003 TM-7 satellite image using GCP's , previous methods and experience.
- Conduct a land use/land cover change analysis 1993 to 2003.
- Compare changes in land use and land cover changes over this period.
- Submit a report with details of the study (methods, maps and file information), results of the analysis, interpretation of results and recommendations for further studies.

Itinerary of field work in Ethiopia:

March 15	Travel from Nairobi, Kenya to Addis Ababa, Ethiopia.
March 16	Travel to Ghibe Valley (stay at Ghibe station).
March 17-23	Travel around Ghibe Valley sampling.
March 23	Return to Addis Ababa, Ethiopia.
March 24	Return to Nairobi, Kenya

Appendix II. Ground control point (GCP) data sheets

GHIBE VALLEY LU/LC GROUND SURVEY - MARCH 2003

DATE: DAY.MONTH.YEAR eg 12.3.97

lot Numbe The number of the plot as marked in the GPS (waypt)

Region: Ghibe, Gerangera, Gullele or Kumbi/Area=closest village or landmark

LU/LC Typ WG=Wooded grassland, RIP=Riparian, RIP CULT=Riparian cult., CULT=lo-density small-holder cult., HICULT=Hi Density small-holder Cult., FA=Fallow Forest, GRL=Graze land, PR=Path road, TUK=Tukel

Photo Number: Exposure number or -99=No photo taken.

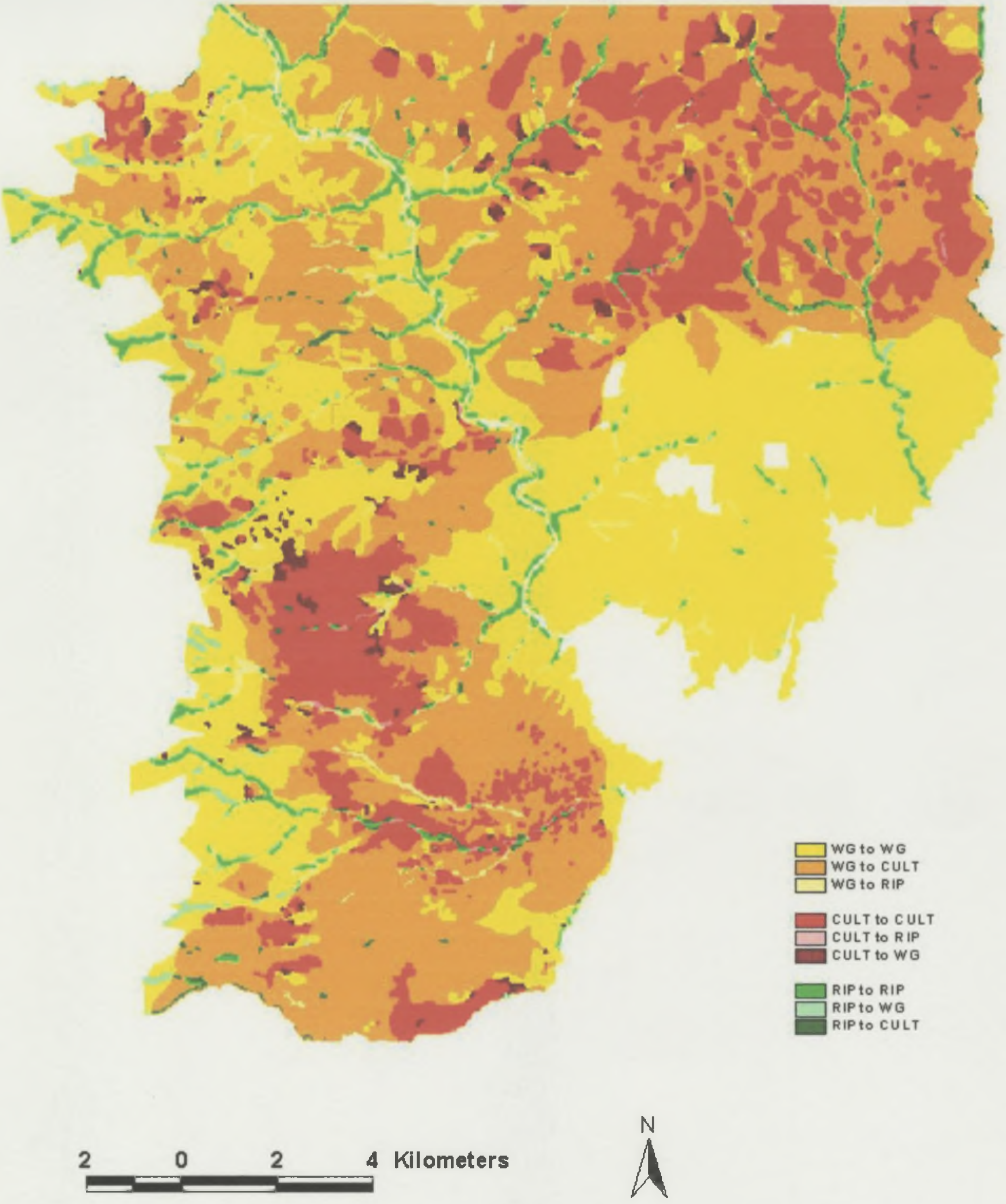
												Estimated % Tree/Shrub/Grass/BG			
												Overstory		Understory	
Date	Time in 24hrs	Plot (way pt)	GPS Northing	GPS Easting	Region	Region Abbrev	Photo #	Compass Bearing of photo	LU/ LC Type	Burn?	Soil Color	Tree	Shrub	Grass	BG

Appendix III. Filenames and descriptions of Ghibe data (included on cd with report).

Filename	Type of File	Extension	Description
ghibe study regions	vector	.shp	Ghibe region boundaries
ghibe boundary	vector	.shp	Ghibe study site boundaries
ger bnd	vector	.shp	Gerangera study site boundaries
gull bnd	vector	.shp	Gullele study site boundaries
kum bnd	vector	.shp	Kumbi study site boundaries
rivers ghibe	vector	.shp	Ghibe region rivers
m-rivs	vector	.shp	Main rivers of Ghibe region
road ghibe	vector	.shp	Roads of Ghibe region
ger cult	vector	.shp	hand interpreted polygons Gernagera cultivation
ger rip	vector	.shp	hand interpreted polygons Gernagera riparian
ghb_st_farm	vector	.shp	hand interpreted polygons Ghibe state farm area
ghb cult	vector	.shp	hand interpreted polygons Ghibe cultivation
ghb rip	vector	.shp	hand interpreted polygons Ghibe riparian
kum cult	vector	.shp	hand interpreted polygons Kumbi cultivation
kum rip	vector	.shp	hand interpreted polygons Kumbi riparian
gull cult	vector	.shp	hand interpreted polygons Gullele cultivation
gull wg	vector	.shp	hand interpreted polygons Gullele wooded grasslands
gull rip	vector	.shp	hand interpreted polygons Gullele riparian
minmain2	raster	folder	River buffer
ghib93rx	raster	folder	'1993' ghibe data used for mask
ger93rx	raster	folder	'1993' gerangera data used for mask
gull93rx	raster	folder	'1993' gullele data used for mask
kum93rx	raster	folder	'1993' kumbi data used for mask
ghbmax	raster	.tif	Corrected '1993' ghibe data
germax	raster	.tif	Corrected '1993' gerangera data
gullmax	raster	.tif	Corrected '1993' gullele data
kummax	raster	.tif	Corrected '1993' kumbi
ger93lu	raster	folder	Corrected '1993' gerangera data
ghb93lu2	raster	folder	Corrected '1993' ghibe data
gull93lu	raster	folder	Corrected '1993' gullele data
kum93lu	raster	folder	Corrected '1993' kumbi
ghibe03lu	raster	folder	2003' Ghibe lu map
gerlu_03	raster	folder	2003' Gerangera lu map
gull2003lu	raster	folder	2003' Gullele lu map
kum03lu	raster	folder	2003' Kumbi lu map
ghibe93_03lu	raster	folder	Change map for 1993-2003 Ghibe area
geran93_03lu	raster	folder	Change map for 1993-2003 Gerangera area
gulule93_03lu	raster	folder	Change map for 1993-2003 Gullele area
kumbi93_03lu	raster	folder	Change map for 1993-2003 Kumbi area
ghibe1993_2003lu	AV project	.apr	LU analysis AV project
GCP data			
GCP Data Sheet	excel	.xls	Blank GCP field data sheet
GCP data set 2003	excel	.xls	GCP data set 1
GCPs second set 2003	excel	.xls	GCP data set 2
Image files:			
ghibe345_8	image	.tif	Unclassed image of Ghibe Region, Bands 345_8
ghibe347_8	image	.tif	Unclassed image of Ghibe Region, Bands 345_9
uscomp345_8_15	image	.tif	Unsupervised classification Bands 345_8
Ghibe_5sc	image	.tif	Supervised classification of 2003 image
Gull_sc5_34m	image	.tif	Supervised classification of 2003 Gullele area
Final report on Ghibe LU Change 1993-2003	word	doc	Consultancy Report Ghibe LU/LC Change 1993-2003
Ghibe file list.xls	excel	.xls	List of Ghibe files
Field Photos	jpeg	.jpg	Photos at GCPs

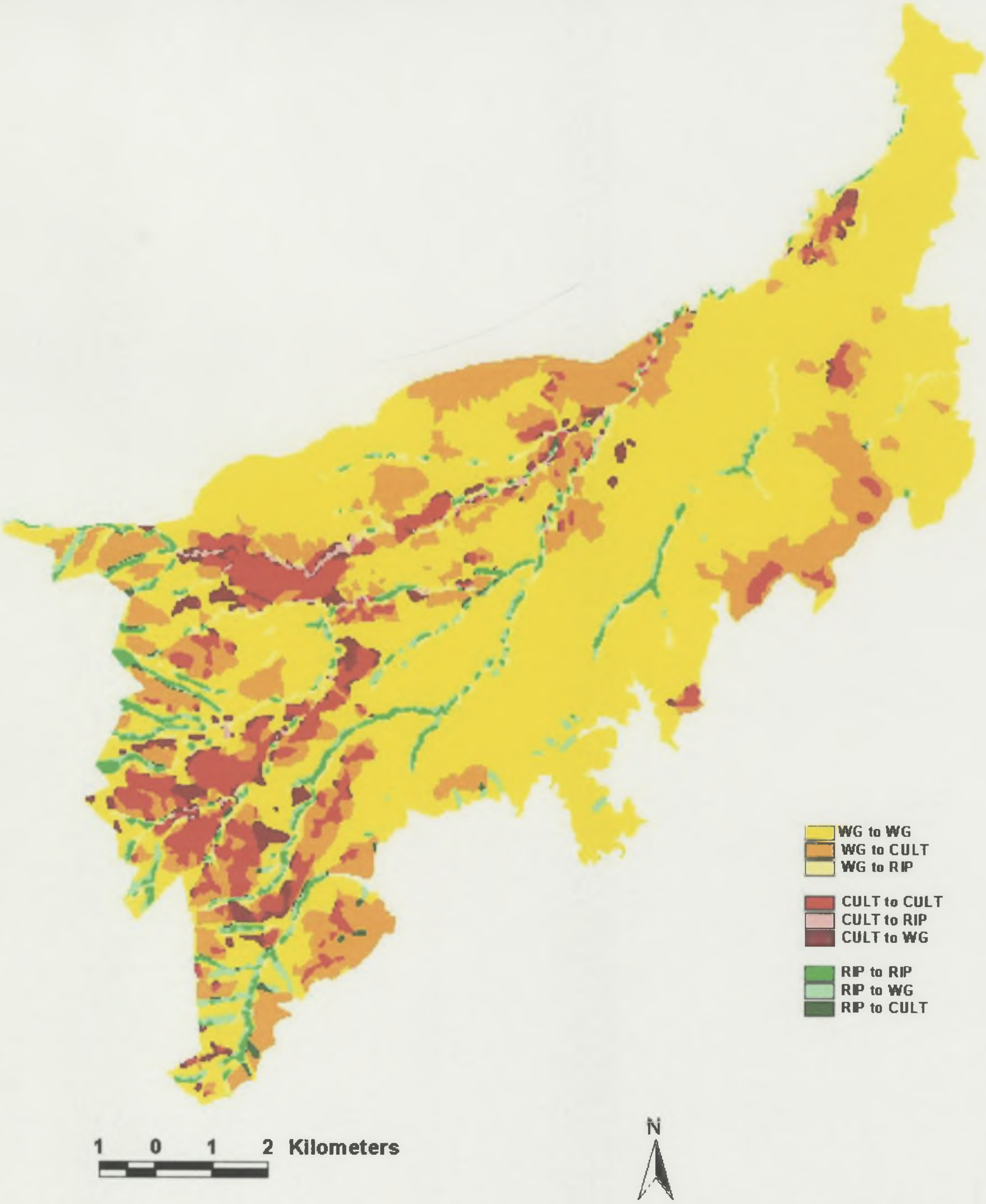
Appendix IV a-d. Maps showing changes in land-use/land cover at each study site in Ghibe Valley, Ethiopia.

Appendix IV.a. Land-use/Land Cover Change at Gullele study site, 1993-2003.



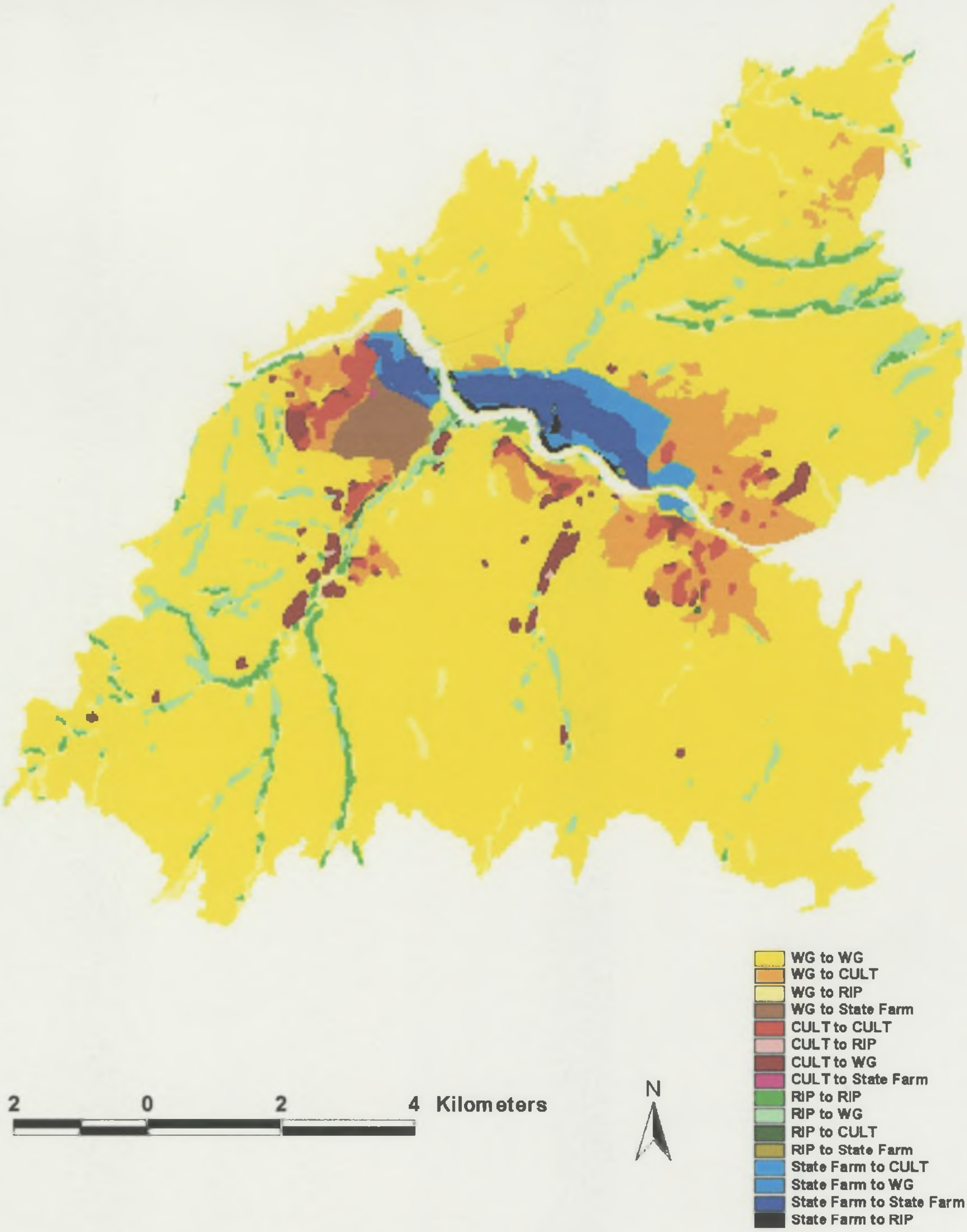
Note: WG=Woodland Grassland, CULT=Cultivation, RIP=Riparian Woodland, Plantations shown in white not presented here.

Appendix IV.b. Land-use/Land Cover Change at Gerangera study site, 1993-2003.



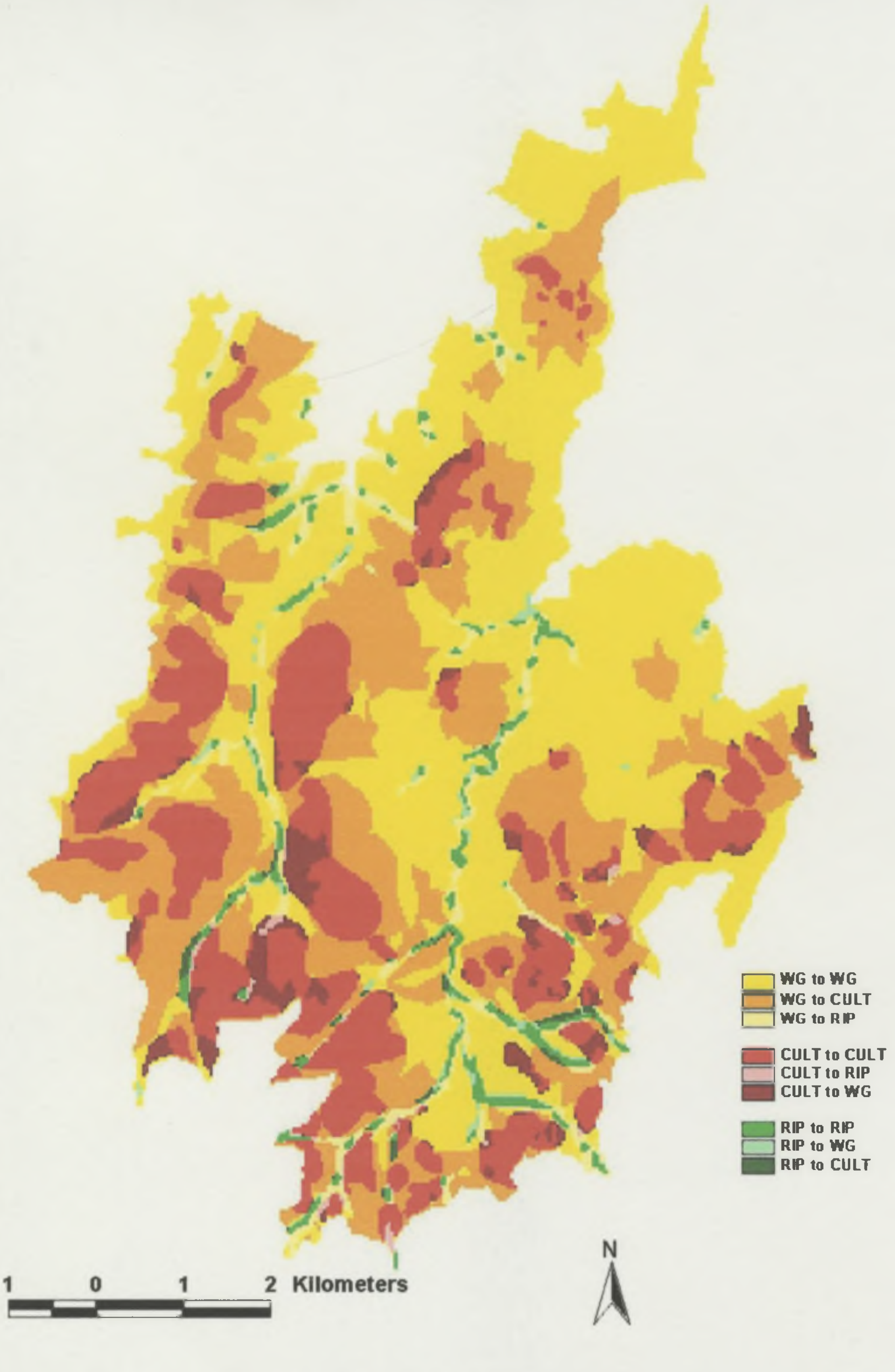
Note: WG=Woodland Grassland, CULT=Cultivation, RIP=Riparian Woodland

Appendix IV.c. Land-use/Land Cover Change at Ghibe study site, 1993-2003



Note: WG=Woodland Grassland, CULT=Cultivation, RIP=Riparian Woodland, State Farm is State Farm (largeholder farms).

AppendixIV.d. Land-use/Land Cover Change at Kumbi study site, 1993-2003



Note: WG=Woodland Grassland, CULT=Cultivation, RIP=Riparian Woodland.